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TEXTILE INSTITUTE

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THE JOURNAL OF THE
TEXTILE INSTITUTE

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PROCEEDINGS

NOTES AND NOTICES

COMING-OF-AGE CELEBRATIONS

The President of the Institute (Lieut-Col. B. Palin Dobson) and the Chairman of Council (Mr. F. Nasmith) are taking a most active interest in the promotion of arrangements in connection with the celebration of the Coming-of-Age of the Institute, and have already attended committee meetings at which preliminary measures have been fully explored. The dates for the holding of the Celebration Proceedings are now definitely fixed—22nd to 25th April next, at Manchester. Members are asked to make note of the dates and to assist in promoting the success of the movement. It is particularly hoped that every effort will be made by Members in the direction of advancement of the membership strength during the present year. Whilst applicants for membership continue to come forward with encouraging regularity at each monthly meeting of Council, yet, as a result of the prevailing industrial depression, withdrawals arise from time to time and the progressive enrolment is thereby discounted. In regard to new-member proposals, the forms of application have recently been revised. The Secretary would be pleased to supply forms on request.

OUTLINE OF PROGRAMME

At last meeting of the Coming-of-Age Committee, progress reported in relation to various decisions and instructions enabled a broad outline of the celebration proceedings to be visualised. It is proposed that the proceedings shall begin with a reception on the evening of Wednesday, 22nd April. On the morning of Thursday (23rd) the Annual Mather Lecture will be contributed, Dr. W. Lawrence Balls having already accepted invitation to provide this contribution. A paper, probably on the subject of Technical Education, will follow and it is expected that Mr. A. Abbott (Board of Education) will be the contributor. After luncheon, visits to various works and institutions are contemplated and in the evening a banquet will be held and many guests will be invited. It is hoped that it may be possible to arrange for the broadcasting of the principal utterances on this occasion. A departure from the usual course of events in connection with meetings promoted by the Institute will be the arrangement of a special lecture open to the general public. The lecture will be of popular interest and will be given by the distinguished contributor, Sir Leonard Hill, who will deal with some scientific aspects of clothing. On the Friday (24th April) there will be a morning session at which papers will be contributed by representatives of Research Associations, and the aforementioned public lecture will take place in the afternoon. In regard to the Celebration Proceedings as a whole, the Committee is confident that a really excellent measure of influential support will be forthcoming, and

Lord Derby has already expressed willingness to attend and take part in some portion of the proceedings if the dates prove suitable.

The Warner Memorial Medal

Since the decision of the Council of the Institute to establish a Medal to perpetuate the memory of the late Sir Frank Warner, a distinguished President and for many years Chairman of Council, arrangements have proceeded in regard to design and other details of production of the medal. It is expected that the medal will be available at an early date and that award or awards may be decided upon prior to the Coming-of-Age Celebrations. In this event, any presentation would form part of the celebration proceedings The medal is to be available for award in respect of published original investigations in textile technology; the awards to be made at interval of from two to five years. The Coming-of-Age Committee recommended to Council that, even though it might thereby be necessary or desirable to award more than one medal on the first occasion, the question of selection to cover all the requirements up to 31st December 1930 should be considered.

Council of the Institute

In accordance with the requirements of the By-Laws, the names of members of Council of the Institute due to retire at the next Annual General Meeting (1931) are set out below. Members of Council are elected for three years, unless election has taken place in respect of a casual vacancy, in which case retirement takes place in the order which would have applied to the member whose withdrawal created the casual vacancy. Of thirty Councillors, ten retire each year. In the 1931 and 1932 lists there are only nine names recorded in respect of the 10 vacancies which will arise, as there is one casual vacancy in each list at the time of compilation of this record. Later, and in time for the next Annual General Meeting, nomination forms will be issued to Members. The order of retirement of Councillors is as follows—

1931	1932	1933
Bailey, R G.	Binns, H	Barwick, F W
Bailey, W	Cockcroft, E E	Beveridge, J P
Chance, F S	Fletcher, J F.	Boothman, W I
Davis, W	Read, J	Bromiley, H
Hall, A J	Richardson, H	Kershaw, W
Lishman, W W. L	Robinson, T H	Morley, T
Midgley, E	Slater, F P.	Morton, W. E.
Nisbet, H	Speakman, J. B	Robinson, J
Wilkinson W	Wigglesworth E	Watson, S.
		Withers, J C.

Institute Membership

At the December meeting of Council, the following were elected to Membership of the Institute—N. V. Astbury, 51 Chorley New Road, Bolton (Cotton Carder); H. Beevers, 23 Gladstone Terrace, Elland, Yorks. (Worsted Spinning Overlooker); R. D. R. Bell, Elgin Mills Co. Ltd., Cawnpore, India (Office Assistant); W. N. Bignall, 6, 2nd Avenue, Sherwood Rise, Nottingham (Hosiery Factory Manager); H. Dawson, B.Sc.Tech., "Thornham," Windsor Avenue, Penwortham, Preston (Textile Chemist); J. K. Ebblewhite, 4 Waverley Avenue, Beeston, Nottingham (Publicity Manager); T. F. Griffin, Technical College, Bradford, Yorks (Combing and Spinning Instructor); J. W. Howson, 21 Cromer Avenue, Tonge, Bolton (Asst. Manager, Cotton Manufacturing), S. H. Kay, A.M.C.T., 47 Richmond Street Newton Heath (Operative Cotton Spinner); R. H. J. Milne, B.Sc.Tech., A.M.C.T.,

Charlton House, Prestwich, Manchester; T. A. Purt, 1 Horsefair Street, Leicester (Rep. of Textile Winding Machine Builders); A. Ratcliffe, 80 Manchester Road, Walkden (Student); E. Shires, c/o 101 Bartholomew Street, Leicester (Senior Textile Engineering Draughtsman); E. Tanner, Westholme, Mossley, nr. Manchester (Mill Manager); H. Witter, 59 Milnrow Road, Shaw, Oldham (Cotton-room Assistant).

Lancashire Section

Meeting at Stockport College, Stockport, on Wednesday, 26th November 1930, *Mr. J. I. Higson presiding*

DEVELOPMENTS IN WINDING AND DOUBLING

Prior to the lecture which was delivered by Mr. Walter Bailey, Councillor W. H. Downham, Vice-Chairman of the Stockport Education Committee, who attended in the absence of the Chairman of that Committee, extended a welcome to the Textile Institute on behalf of the Governors of the College and said that the Institute was doing a great work, which was especially helpful during this time of trade depression. It set an example and encouraged others to follow. Such lectures as the present one did much to improve the working conditions of present and future employés. He had had an opportunity of seeing the *Journal of the Textile Institute* and was interested and impressed with the variety of subjects covered. It was with great pleasure that he gave the official welcome and he expressed the wish that the Textile Institute's future activities would be attended with all possible success. The great aim was to inculcate in its followers that it was only the idler to whom work was a curse.

Mr. Higson in introducing the lecturer said that the subject was one which was well suited to the needs of Stockport—the hub of the doubling trade, in which 10,000 persons were, normally, engaged. Unfortunately this section of the textile industries, like all others, was at the present time suffering from the effects of the world depression, and also to some extent from the increased production of artificial silk. This industry had at times been of assistance to the doubling trade, but for the most part it was a serious competitor especially in the stocking trade, since upon the production of yarns for stockings, Stockport had been largely dependent.

The Lecturer said that the title of his lecture did not indicate that he would deal with the development of the winding and doubling industries historically. This had been done adequately elsewhere. He then briefly described the two main principles upon which winding machines are made. Although the type was one of the simplest and oldest in use, upright-spindle winding frames of larger gauge and stronger build were now used. Frames of 6-in. gauge with about 9½-in. lift were being made and wound a taper bobbin containing about 1⅜ lb. of yarn. Great improvements having been effected in cam and traverse motions, the quick-traverse winding frame, fitted with patent wire traverse and differential motion was generally used for assembling two or more ends for the twister creel. Quite recently patent top-runner bowls with stationary flanges, and patent ball-bearings for the drum shafts had been applied to these machines; a number having 7 in., 8 in. and even larger traverse were in use.

A development of the last few years, continued the lecturer, was the introduction of high-speed cone-winders for single-end packages. This machine owed its success not only to its high speed but to the form of packages built—a cone. These cones had been in great demand for the hosiery trade and for high-speed beaming. The principles of the machines were described and illustrated by the lecturer. Mr. Bailey next turned to twisting and again dealt primarily with the principles upon which the machines were built. The use of the intermittent

system was not extending, said Mr. Bailey, and the same remark applied to the flyer system: the ring-twister must now be considered pre-eminent for the doubling of all counts of cotton yarn. Tape driving of spindles had been largely extended. Rings used in ring doubling had received a fair amount of attention said the lecturer, and described two new types of self-lubricating rings. Increased spindle speeds up to 30% had thus been secured.

Thirty years ago, the Lecturer continued, the industry knew little of the production of folded cable yarn; now 700,000 bales of cotton per annum went into these yarns in the United States alone. The doubling frame mainly in use to-day was of the ring-type and was of specially strong construction. The rollers were arranged to obtain a definite grip on the yarn and thus to prevent pulling through. The introduction of a specially-made spindle had been necessary. There were now in use spindles which revolved freely and without vibration at high speeds and which carried a bobbin containing 3–3½ lb. of yarn. Finally, Mr. Bailey described the new twisting frame, introduced by Messrs Andrew & Langstreth of Rochdale, for which it was claimed that having none, traveller troubles were eliminated, and that snarls consequent upon starting and stopping hard twisted yarns were obviated. The lecture was well illustrated by lantern slides.

Discussion

Mr. Higson called upon Mr. H. P. Greg to propose a vote of thanks. Mr. Greg said that in his own mill he tried to think that there was nothing right in it from start to finish, though of course there must be something, however small. Mr. Bailey had laid much stress on the importance of the tape drive and it was perhaps on that account that he had been asked to propose the vote of thanks as he was somewhat responsible for the introduction of the tape drive in this country. Mr. Greg continued that a friend of his invented a small attachment for the loom, and a little later saw the identical thing on a machine maker's scrap heap; his friend had re-invented a 30 year's old invention. He was glad so many had seized the opportunity of learning something from Mr. Bailey. Personally he felt most indebted to him for the clear description of the various points he had brought before them. In industrial life as in everything else, it was easy to think only of self, but it was far more important to think of others. He had great pleasure in proposing a hearty vote of thanks to Mr. Bailey.

Mr. Joseph Morris in seconding the vote of thanks said he considered those present were most fortunate in having as lecturer, Mr. Bailey, who had such a wide experience of his subject. Apart from the pleasure of listening to a lecture delivered by a Fellow of the Textile Institute, he had the additional pleasure of listening to his old teacher, and he was glad to be called upon to second the vote of thanks.

Mr. Bailey in reply said he greatly appreciated the vote of thanks and especially the way in which it had been proposed and seconded.

Scottish Section

Meeting at Galashiels, Thursday, 11th December 1930

In the afternoon, by courtesy of Messrs Sanderson & Murray, Ltd., a visit was paid to the firm's skin works, where the party was received by the Managing Director, Mr. Addison, who conducted the visitors through the works. During the tour of inspection, members had an excellent opportunity of viewing the different processes employed by the firm in the treatment of sheepskins and the grading and preparation of skin wool, followed by the subsequent softening and preserving of the skins for various purposes. The party spent an interesting afternoon and greatly appreciated this privilege.

In conjunction with the Scottish Woollen Technical College, an evening meeting was held in the College, Galashiels, at 8 p.m. under the auspices of the Selkirk County Education Committee's Series of Specialist lectures in textiles. Mr. G. D. Gibson (Selkirk) presided over a large attendance, including members of the Institute and students of the College. The Chairman introduced the Lecturer, Mr. J. McIsaac, A.T.I., Principal of Wilts. County Textile School, Trowbridge, and drew attention to the fact that Mr. McIsaac had been a student of the College before going to Trowbridge to take up his position there. He took the opportunity of thanking the Committee of the Scottish Section for their part in arranging the meeting, and expressed the hope that it would prove an interesting and instructive evening.

Mr. McIsaac thereafter showed a number of lantern slides illustrating the various machines used in the process of cloth Finishing, in order that the audience might be familiar with these when mention was made of them in the course of the lecture, and also for the benefit of those not directly engaged in the industry. Afterwards, he gave an interesting address on cloth Finishing, particularly as applied to the West of England trade, detailing the various processes and the methods employed in the preparation of different types of West of England cloths. Discussion followed, and among those taking part were Dr. A. W. Stevenson and Messrs Christie and Sinclair (Galashiels).

Mr. A. W. Blair (Hon. Secy.) moved a vote of thanks to Mr. McIsaac, expressing, on behalf of the Section Committee, appreciation of his kindness in coming such a long distance to address a meeting of the Section, and also thanking Dr. A. W. Stevenson and the College Authorities for their assistance in connection with the meeting.

Mr. McIsaac, in reply, said that he had enjoyed his visit to Galashiels and meeting old friends in the district, and he thanked the Scottish Section Committee for affording him the opportunity of doing so.

London Section

Public Lecture at the Barrett Street Trade School, W1; Mr. H. J. Clarke presiding

SOME DISTRIBUTORS' PROBLEMS

The lecture reported below was delivered by Mr. J. G. Williams, chief chemist, Selfridge & Co. Ltd., London. In introducing his subject the Lecturer said he proposed to confine himself to textiles and therein only to deal with a few problems; he would discuss some defects of textiles and the complaints received. He had not been able to secure exact statistics of the proportion of complaints to transactions but those available indicated that these number of complaints was probably less than one per thousand and that half these proved to be due to misunderstanding. The first consideration was the economic principles underlying the distributor's problems. There were more sellers than buyers, said the Lecturer, and so the buyer could secure keener values; but there was a limit to price concessions. Competition among sellers ultimately meant lowering of real quality. Obviously goods of an apparent quality but actually inferior did not give satisfaction in the long run. The Lecturer urged that the best course was to give the maximum quality possible at any given price level.

Mr. Williams then discussed the ascertainment of qualities of which he submitted that the two most important were "fitness for intended purpose" and "rendering of satisfactory length of service." These qualities were not measurable by cost of raw materials used nor by wages paid. The standard to be aimed at was "to make and sell goods that did not come back," and in the opinion of the lecturer this was a higher standard than "to make and sell goods that did

not come back to an embarassing extent." Such a policy was being followed and unless the goods were very bad, since customers were usually very tolerant, the vendors continued in business. This standard was, in the opinion of the lecturer, undesirable. The higher standard could only be achieved by securing that any and every complaint was properly investigated. To carry out such investigations was an expensive process: in some instances firms, either distributors or manufacturers, were large enough to conduct their own research and testing departments. But in his opinion, continued the Lecturer, the problem was one of mutual importance to retail and wholesale distributors and to manufacturers, and they should recognise their common interests and take common action. This question of common interests amounts to the need of the textile industry as a whole to maintain or increase its proportion of the national income: all parties in the industry are and must be interested in this problem.

The Lecturer then proceeded to discuss this proposition for the mutual investigation, by all interested sections of the textile industry, of the properties of textiles as they affect the interests of the consumer. These investigations, he urged, were not being made and no machinery existed to make them. He urged the establishment of a General Textile Research Association and outlined its functions. Its preliminary work would be the investigation and study of complaints received by retail distributors. The Lecturer here gave a brief account of the work in this direction carried out by the retail house with which he was associated; he gave a table of classified results of over 750 investigations and pointed out that the principal defects were (1) defective colour fastness, (2) shrinkage of fabrics stretched in finishing, (3) insufficient strength either in yarn or due to structure or tendering, (4) thread slippage. All these he suggested, were controllable to a very large extent, and discussed at some length means that might be taken in remedy. He then returned to consideration of the functions and work of the General Research organisation to which he had previously referred. He considered that the next stage of the work of such an organisation would be that of standards, both of description and procedure. Misuse of merchandise would also be studied, as well as the needs for and extent of what is termed "Simplified practice" In the view of the lecturer this work could not be done by the existing Textile Research Associations and would necessitate the establishment of a separate and special organisation. In his opinion we possessed the capital, the skilled labour, and the brains. With co-operation within the industry and with the use of science we could secure the results at which we aimed.

Mr. J. H. Lester moved and Mr. E. B. Fry seconded the according to Mr. Williams of a hearty vote of thanks for his lecture: this was given with acclamation.

REVIEWS

"Historic Costume." By Francis M. Kelly and Randolph Schwabe. (B. T. Batsford Ltd., London; 25s.)

This is a second edition of a work which depicts and describes the fashions in Western Europe between 1490 and 1790. The authors emphasise the claim that from first to last they have preferred to depend upon contemporary witnesses, pictorial and literary, so as to achieve a thoroughly reliable guide for the benefit of the artist, actor, film producer, and other interests. The book is excellently illustrated both by reproductions of contemporary paintings and beautiful pen drawings of Mr. Schwabe, the latter being remarkably interesting for their wealth of detail of the fashionable dress of the three centuries covered. The accompanying descriptive matter explains the features of the costumes and the associated items of dress. The book could be profitably studied by many interests beyond those already mentioned.

T.

Technologie der Textilfasern. Volume II. Part 2—Die Weberei. (Julius Springer, Berlin, 1927; 36 RM.)

The volume under review is the second of a series of valuable books, edited by Professor Dr. R. O. Herzog, of Berlin, on almost every branch of Textile Technology. "Die Weberei" is written by Dr. Ing. A. Lüdicke, of Brunswick. Professor K. Fiedler contributes the section on the weaving of ribbons and braids. The third part deals with the construction of weaves, the "Bindungslehre," the author being Mr. Johann Gorke.

The task of compiling a great deal of fundamental information on weaving of various textile materials has been successfully achieved by Dr. Lüdicke. The reader must not expect, therefore, to find in this book detailed accounts on any special branch. This is probably better available in the English language; Germany seems to favour this type of "Handbuch." The particular value of this book lies in its general appeal to the engineer, the manufacturer, the student, the research worker, or to anyone finding interest in the technology of weaving. Despite this the style is never vague or general. Very few books are written in such concise and accurate style. The numerous references to recent German patents are very helpful, and in most cases references are also made to special publications, books, and articles. Modern automatic looms are fully described. The reference to the "Giehler loom" which, according to the author, constitutes an important development for the future, is very interesting. This is a loom where the shuttle is led through the shed in a positive manner and without touching either reed or warp and where the bottom warp line does not rest on the slay. As on the "Souczeck" loom, no picker is employed and the loom therefore runs quietly and fast without vibration. A trial loom, weaving 78 in. cotton sheetings, was timed at 112 picks per minute. The chapters on buildings, social and welfare work give a good deal of information on the German industry from these aspects. It is somewhat strange to the English reader to find in this book a section on "Finishing." This is a reflection of the organisation of German textile industry. Although the author explains at the outset that he must restrict himself to the purely mechanical processes, it is even then impossible to do justice in 40 pages to such a highly specialised and important subject. One feels that this section should appear in a separate volume. A specially interesting section on the weaving of pile fabrics and carpets is contained in another volume of the "Technologie" Series, and it might perhaps be appreciated much more as a section of the "Weberei" instead of this review of the finishing processes. An index of literature on the subject has been added but it does not mention recent English publications. An author's index would have enhanced the value of the book as well as an index list of the patents. The subject index at the end is accurate and reliable.

Professor Fiedler's contribution on the machinery used in the manufacture of ribbons and braids will be generally appreciated. Almost every part and motion of a ribbon loom is dealt with exhaustively with the aid of a large number of line diagrams and photographs. Reference is made to German, Swiss, English, and American types of machines and their relative merits and practical advantages are stated. The author also expresses his views of breaking with convention and convenience for the sake of adaptation of the latest types and he demonstrates the successes of engineers in construction of the modern ribbon looms, which are indeed great mechanical achievements.

The third section, by Mr. J. Gorke, is a very lucid and concise course of the "Bindungslehre"—the construction of weaves. The essential facts and methods are given of simple weaves and derivatives as well as pile structures, double, and treble cloths. There is no unnecessary elaboration and the grouping of examples on separate tables will be found very convenient.

"Die Weberei" is a valuable modern contribution to textile literature. The great number of illustrations (854 in the text) and the numerous photographs make it accessible to the student who does not possess an exhaustive knowledge of German and interesting to anyone wishing to be informed of the world's progress in textile and weaving technology. The printing and binding reflect credit on the publishers. Later editions might be corrected by eliminating a few typographical errors.

R.O.K.

The "Textile Recorder" Year Book, 1931. Published by John Heywood Ltd., Manchester (898 pages, 7s. 6s. net).

This Year Book appears with the announcement that the Rayon Section has been entirely revised and new sections on rayon sizing practice and the dyeing of rayon have been introduced. A step in the right direction has been taken by the introduction of a section on "Microscopy: the hairs and fibres of Commerce," and a page of drawings purporting to represent various fibres has been eliminated whilst micro-photographs of the chief "fibres of commerce" have been substituted, There is some difficulty in criticising this and other year books constructively as it is not easy to determine whether the volume is to be regarded primarily as a new and revised edition of a text-book or as a book giving a picture of the events and progress in the textile industries during the past year. If regarded as a text-book then the statistical and commercial portions are out of place; if regarded as a year book then the repetition each year of a large proportion of the volume is unnecessary. These annual volumes usually contain a mass of information which once on your shelves does not need to be duplicated and also additional matter each year which is also worth adding to a textile library. The combined effect is somewhat embarrassing. T.

Worrall's Textile Directory of the Manufacturing Districts of Ireland, Scotland, and Wales, with the Dominions of Australia, Canada, and New Zealand, and the Counties of Chester, Derby, Leicester, Nottingham, etc. Published by John Worrall Ltd., Oldham (284 pages, price 13s. 6d. post free).

The 41st Edition of this Directory bears evidence of the attention paid by its publishers to its typography, paper, and general make-up; it is much improved. The "Contents" page is a useful addition. This volume offers a definite indication of the spread of textile manufacture throughout the British Isles (exclusive of course of Lancashire and Yorkshire) and in the Colonies mentioned in the title. The series of directories of which this volume is a unit are a reliable guide to the industry they set out to serve. T.

The "Chemical Age" Year Book, Diary, and Directory, 1931. Published by Benn Bros. Ltd., London (160 pages, 10s. 6d. net).

This Year Book, which combines the other functions indicated in the heading, constitutes a useful directory of commercial and technical information and also contains a diary of the one-week-per-page type. The two aspects of the volume are rather difficult to combine effectively; the diary is too big for desk use but the page size chosen affords ample space for display of tables, etc. One leans towards the solution of eliminating the diary. T.

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PROCEEDINGS

London Section

Lecture at the Institute Rooms, Newgate Street, London, Wednesday, 3rd December 1930; Mr. A. Mason in the chair.

NEW MOTIVES FOR TEXTILE DESIGNS

This meeting took the form of an address and a demonstration of crystallisations seen through the microscope by polarised light. The speaker was Mr. F. G. Wood, who said he was glad of an opportunity to show his work to a textile gathering. The beauties of crystallisation in some of its many forms had of course long been known, whilst through the microscope many people had become familiar with the less common crystals. His investigations had been directed not only towards a means of making these lovely forms and colours available to designers and other interested, but to enhance their value and beauty by the use of polarised light. He did not think crystal forms seen thus had been explored as a source of designs and colour schemes. He also pointed out that the slides exhibited were those of his own choice and might embody colour schemes not acceptable to all. In addition it was to be noted that it was difficult to provide a large audience with a projected image big enough for all to see and yet sufficiently defined to retain the delicate shades the smaller projections revealed. A smaller downward projection of 15 in. diameter was available for use after the lecture. The lecturer then showed three series of slides, the first being those of substances upon which he first began to work, then those of substances specially compounded by himself for this purpose and finally a series designed to exhibit the range of variation possible upon any chosen theme. After the demonstration Mr. Wood was cordially thanked for his services

Lancashire Section

Meeting at the Institute, Wednesday, 10th December 1930; Mr. W. T. Boothman in the chair.

TRANSPORT IN RELATION TO THE TEXTILE INDUSTRY

The lecturer, Mr. A. J. Green, of the Calico Printers' Association, was introduced by the Chairman, who said that he felt sure those present would have a valuable lecture, as Mr. Green was a practical man and well qualified to deal with this subject.

Mr. Green pointed out first how much time cotton, either as raw material, yarn, or cloth, spent in transit from one place to another, from spinner to manufacturer, and thence to finisher and finally to merchant and consumer. No other material known to industry passed over such long distances during manufacture and sale. He then turned to the question of transport within this country and exhibited figures for the transport, by rail, of one ton of cotton from point

to point until finally it reached London as finished goods. On a broad average these charges worked out at about 4d. a piece of 30 yards. The next aspect to be treated was the growth of direct cotton importation to Manchester since the opening of the Manchester Ship Canal. This was shown to have increased tenfold since 1894, whilst the tonnage of raw cotton sent inland by rail from Manchester had more than doubled in the past seven years. But, the lecturer pointed out, the difference was more marked if the road transport figures were considered and showed tables of comparison with Liverpool indicating the turn over from rail to road and from Liverpool to Manchester. The lecturer then compared and contrasted road and rail transport, giving at the outset a comparison of the obligations imposed upon a railway company and those upon a haulier which were entirely in favour of the latter. A table of present day railway rates on raw cotton from Liverpool was shown in which comparison was made with those in force in December 1927, and pre-war rates; it was noteworthy that present day rates in every case were lower than pre-war rates. Credit for these reductions in rates had to be assigned, said Mr. Green, to the Cotton and Allied Trades Transport Committee. An outline was then given of the domestic transport system of the Calico Printers' Association as being typical of the transport systems of other large combines. The motor-fleet system on a properly organised basis could be run, at rates which compared very favourably with railway rates, at any rate within a radius of 40 miles from Manchester. The actual costing figures quoted by Mr. Green, showed that the inclusive cost by road was better than that by rail by margins as high as 5s. 3d. in some cases and as low as 1s. 5d. in others, whilst in special instances rail charges were better than road charges to the extent of 1s. 10d. On the whole the balance was in favour of road transport on cost, whilst on speed and convenience the advantage appeared to be overwhelmingly on the side of road transport. Two further aspects of the transport problem were touched upon by Mr. Green, the use of horse transport, and the use of the Fordson tractor. The margin of cost, said the lecturer, was well on the side of the one-horse vehicle, and had this not been so, no amount of sentiment would keep the horse on the road. The heavier loads conveyed by two horses cost about 34s. a day, whilst the Fordson tractor returned a cost of 36s. a day. But the amount of work done by the tractor was much greater and the real balance was in its favour. In conclusion, Mr. Green referred briefly to the handicap under which British exporters suffer by reason of the lower freight rates from Continental ports than from Liverpool or London. He described effects made to secure amelioration of these conditions but said he feared he could suggest no immediate remedy. Cheaper Continental working conditions and geographical advantages were insuperable barriers.

Discussion

The discussion was opened by a representative of one of the railway companies, who said that he appreciated the way in which Mr. Green had dealt with his subject. The railway companies would not have contributed by reducing their rates to the help of the cotton industry unless there had been such an organisation as the one to which the lecturer referred. The Chairman had referred to traffic by road between Bolton and Oldham and he would like to remind everyone that as the railway traffic system was organised at present, goods had to be sent by night. An inter-day service might be given by joining forces with the road companies. There was also the question of expensive packing of goods for export which hitherto was thought to be most necessary and was exceedingly well done. But cheaper methods could now be taken advantage of, as some of the shipping firms supplied containers for removing goods to the docks. The railway companies were prepared to supply containers which were not handled again until they got to the ship side. In his motor charges he wondered if Mr. Green had covered overhead charges. The Road Act would increase

the costs of motor transport and this would bring the scale nearer to that of the railway companies.

The Lecturer, in reply, said that he had included nothing in his figures for overhead charges in regard to motor transport. Simply the cost of running the motor.

Another speaker said that he also had very much appreciated the lecture; he never missed an opportunity of listening to Mr. Green. Referring to the sheet of rates provided by the lecturer, Mr. Tomlinson said that in the raw cotton figures there was a comparison per ton between pre-war and present day, but they only extended to 1925, could this not be extended ? He understood that this would cover the horse rates and wondered if there had been a return to railway traffic from the road because of the reduced rates. He did not think that the road traffic could actually compete with the railway, but the latter often failed because they could not state a charge immediately.

A further speaker said that he endorsed the two previous statements of opinion. The railway companies' rates were not flexible enough and not sufficiently on-the-spot. They could help industry and he thought they were now realising the fact. Mill towns could now get exceptional rates and terms where formally all goods had to be sent at rates as from Manchester. He thought that great saving of time could be made by co-operation between such bodies as the Calico Printers' Association and the mills. For instance, cloth could be delivered direct from the mills to the C.P.A. works without having to come to Manchester first. This aspect of transport might usefully form the basis of a discussion on some future occasion.

The Chairman said he was particularly interested in the question of direct transport from the mills to the various finishing works. He thought that the difficulty in this direction lay in the fact that there was always too much secrecy in trade.

Mr. F. Wright said he had enjoyed the lecture very much indeed and it would enable him to look into one or two points. He thought that the railway companies were now "going through the mill" so that those in industry need not be too hard on them since, after all, the railways were indispensable.

Mr. Green said that the question of abolishing the system of cloth coming into Manchester for forwarding was debated some years ago but no decision was reached as they were up against the vested interests of the cotton trade.

A hearty vote of thanks was accorded to the lecturer.

Meeting at Harris Technical Institute, Preston, 23rd January 1931;
Mr. R. Houghton, J.P., presiding.

Mr. James Smeaton, F.T.I., of the Manchester Chamber of Commerce Testing House, contributed a paper on "Specifications for Textile Materials."* The author referred to the growth of the practice of placing of orders in terms of specifications, submitted a number of typical forms of specifications, and explained the customary tolerances involved.

Several questions were asked and replied to. In answer to the Chairman, the lecturer said they had no experience of terms of specification covering down-proof material.

On the motion of Mr. David Atkinson, seconded by Mr. Fletcher Chadwick, a hearty vote of thanks was accorded the lecturer and chairman.

*The full text of this paper will be published in the March issue of this *Journal*.—EDITOR.

Yorkshire Section

Joint meeting with the Halifax Textile Society at the White Swan Hotel, Halifax, on Wednesday, 14th January 1931.

THE RATIONALISATION OF INDUSTRY

This title was used by Mr. A. Saville, who lectured to the joint meeting held as described above. He postulated that the problems brought by inevitable change were part of human life; we could resist changes and endeavour to preserve the present state or we might prepare for and accept changes as they came. Exaggerated conservatism, however, would not work; the methods of Cato had long been discredited. To meet change it was necessary, now and again, to sit down to take stock. In taking stock we should find some things and methods obviously antiquated and now useless. It was easy to scrap these; it was not so easy to decide which must be restored or reconstructed for continued use. In his view, said the lecturer, it was possible, by action on a reasoned policy, to control the production and distribution of food, clothing, and shelter in such a way as to overcome the tide of difficulties now confronting us—it was possible to survive. The rights and privileges of individuals—only sanctioned by the community—must not impede our action; a new system seemed inevitable, based, perhaps, upon individual sacrifices. Turning to British industry, Mr. Saville said he would take stock therefore in so far as he would enumerate some of the causes which were assigned the present state of affairs; these were—The passing of a trade-cycle; the world-war disturbance; national self-determination; restriction of industrial credits; obsolete monetary policy; increasing burdens of rates and taxes; labour policies, and many which could be summed up as internal administrative and technical inefficiencies.

It was not his intention, said the lecturer, to enlarge upon all these "causes"; his views upon the "internal" causes he had already voiced He proposed to consider some of those "external" factors of change which it was difficult and perhaps impossible and unwise to withstand Of the trade cycle he would suggest that those who looked for such a cycle to bring us back to normal activity and prosperity, should bear in mind cycles may vary in intensity and may become less pronounced in upward movement It was necessary to look up and beyond the cycle to discover and anticipate tendencies and tastes. Many people, said the lecturer, blamed the Great War for all our troubles. To the extent that the disturbed world would include in its reconstruction the latest and best in machinery, plant, and organisation, so far did the war contribute to those changes in external conditions which had had their undoubted effect upon our own industries. We could and must learn that our affairs were but part of a wider world and we must not confine our vision to our own geographical boundaries. We had reached a period in history when the unit in world affairs is the nation and amid international instability a desire for national security was natural and inevitable. There was danger in "waiting for something to turn up" and it would appear that history repeated itself in that defeated countries tended to recover rapidly. We, too, would have to reorganise to meet new conditions.

The existing relations between finance and industry, said Mr. Saville, would have to be examined. At this time of economic crisis greater flexibility of finance was needed; it would appear that money and banking had not shared our losses equally with trade and industry. The heavy calls of national and local taxation were a serious burden upon industry, and prevented the building up of reserves for expansion and development. Turning to labour questions, the lecturer said that the ultimate issue was of the utmost importance. If labour, as it appeared to, demanded a partnership in industry, it was necessary to resist at all costs or to adjust our system so as to make it possible. It appeared to him that the second alternative was the only possible course to pursue, but this did not necessarily

mean nationalisation. Indeed, in the lecturer's opinion, even if public ownership of industry did come, it would, as inevitably pass away again before the march of events.

Dealing with education, Mr. Saville urged that only by offering adequate opportunities could industry appeal to the educated youth. Some form of attraction, either in the form of pay, security of tenure, etc., must be offered and in this respect the larger organisation or the combine was the better placed to make adequate openings. In regard to distribution, the lecturer said that probably none of the important industries was as far out of line with the organisation of distribution as was the woollen industry. The closest link possible between producer and consumer was to be aimed at and one of the most important of present-day problems was to find a way to balance production and public demand. If British textiles were ever to occupy the important position in the world's markets they once held and which it was desired to recover, that position would be secured only by superiority both in product, in selling policy, and publicity.

In conclusion, the lecturer said, "The world of to-day presents us with certain problems old and new. Of the new and difficult situations which confront us I have briefly outlined a number These present a three-fold aspect. They are international (over which only the internationalist financier has control). They are national and over these the industrialist, the economist, and the financier could have, and ought to have, wider control. Finally they are local, concerned with domestic administration Over these we have and ought to exercise full responsibility. Whether we will or not these problems must be faced. and if we will they may be faced with a forward active policy. This policy must be based, if it is to be successful, upon a common agreement and goodwill and upon a common interest for all parties concerned, an interest consisting in the welfare of industry (distinguished from that of private individuals or particular firms) which is ultimately the welfare of society."

Midlands Section

VISIT TO Messrs. WOLSEY LIMITED, ABBEY MEADOW MILLS LEICESTER

On Thursday, 22nd January, a party of 25 members representing five Midland counties paid a visit to the dyeing and finishing section of the Wolsey combine. The members were cordially received by Mr. Sidney Tyler, Mr. Breward, and Mr. Salt, Directors of Messrs. Wolsey Ltd.

The members were shown the various operations required to complete for sale the innumerable types of knitted garments made by the company. The works not only handle the whole of the Wolsey products, but also act as dyers and finishers to the trade. The processes of scouring, milling, unshrinking, dyeing, brushing, pressing, and calendering, etc., were fully demonstrated, thanks to the able directing of Mr. Cattell, Dr. Trotman—who is head of the Research Department—and others. The members, some of whom had not seen this phase of the industry before, were greatly impressed by the efficiency of the organisation in dealing with such an immense quantity of small articles.

Afterwards, tea was kindly provided by the Company and Mr. T. Morley, Chairman of the Section, proposed a hearty vote of thanks to the firm. Mr. Morley stated that he fully recognised the importance of finishing and also that he realised how easily expensive goods might be damaged or spoilt. For that reason, he was quite prepared to remain content to manufacture and allow other firms to finish his goods. Mr. Breward replied that it gave him great pleasure to come in contact with the Institute's members, and trusted that they had enjoyed their visit.

Irish Section

Meeting in the Municipal College of Technology, Belfast, on Thursday, 22nd January 1931; Mr. W. H. Webb (Randalstown) in the chair.

SCIENTIFIC DEVELOPMENT IN THE LINEN TRADE

The Chairman said that he had had a great deal to do with the inauguration of linen research. He had been close to the work and was astonished at how much had been accomplished. In these times we had to be modern and up-to-date. Any industry that was not, or any section of the industry that was not, was a drag on progress, and was bound to go out sooner or later. The world was moving quickly, it did not wait for the laggards; it just brushed them aside. We had to see to it that the linen industry, on which the prosperity of Northern Ireland depended was in the forefront of scientific progress, not only in technique, but in administration and in selling. He was glad to call upon Dr. W. H Gibson, Director of the Linen Industry Research Association to deliver the lecture

In opening, the lecturer stated that although the linen trade belonged to the group of industries in the pre-war period in which scientific research was an external interest, it was one of the first industries in the United Kingdom to establish a research association. The work of framing a policy for the conduct of research was essentially difficult At that time the post-war trend of the trade was unknown, but it was accepted not without reason that after the exceptional trade conditions during the war a steady demand for linen would return and trade would soon settle down to pre-war normality. Under these circumstances problems of production were given places of priority in the programme of research drawn up which, had it been possible to visualise the post-war conditions accurately, might have been given to problems of distribution As a result of the research work undertaken on the raw material side, science has not only accomplished the task of assuring to the trade its supplies of flax in the guise of new pedigree strains, but it has got ahead of the full use that can be made of its work owing to the present economic condition of arable farming. At the present time, assistance to the farmer towards more profitable utilisation of pedigree strains is having the close attention of the Research Institute and a full-scale investigation of retting and scutching has been undertaken. It is hoped that systematic work in the flax factory, built and operated by means of a special Government grant, will establish the value of alternative methods of fibre production and so enable the successful growing of flax to be linked up with the provision of suitable flax fibre for the spinner at an economic price. The object of research on spinning has been to produce the best possible yarn with the minimum of waste. Much information has been gathered which indicates that slight adjustments or modifications in machines and skilful distribution among the series of machines used of the work to be done in breaking down the fibre strands into finer elements may result in better yarn and improved yield. In alterations resulting from research such as the introduction of satisfactory alternative machinery the total effect rather than the intermediate has to be regarded as the deciding factor, owing to the dependence of one process on the other. In the weaving process, as in spinning, scientific development appears likely to take the line of building up upon the sound foundation already laid rather than that of making sweeping alterations. Improvements are being introduced which result in cloths of greater perfection and durability. The bleachers and finishers as a whole have fully realised that their somewhat delicate operations need the strictest scientific control and the result is that they have reached an unprecedented high standard for speed, safety, and economy. The lecturer considered that the linen trade has good reason to congratulate itself upon the scientific manner in which it has investigated its market and the requirements of its customers. The trade does not dictate to the users the form of style of linen with which they can be supplied,

but by means of such organisations as the Irish and Scottish Linen Guild consults the good taste of its customers, listens to their suggestions and does its best to satisfy their requirements. Policies of this kind mean plenty of research work, either for the individual firm or the research associations or both and are now general among the members of the linen industry. In fact it can be seen that the view-point of the industry has been completely changed as a result of the trend of trade during the last ten years. Research work now should really originate at the selling end with the requirements of the user, and it is for members of the Association to bring the requirements of consumers before the Research Association, when steps can be taken to give them the utmost satisfaction.

Although the necessary organisation for co-operative and individual research is now well established, it is felt that in order to reap full advantage from scientific development, the application of scientific method to management problems and a sustained effort to apply analysis, experiment, and measurement to the problems of industrial control are necessary. This fact has been driven home by the report of the Irish and Scottish Linen Industry Delegation on their visit to the U.S.A. and Canada in 1929. It was clearly pointed out that a special type of standardisation was necessary to the industry which would not be carried to such lengths as to destroy the elasticity of the processes and the individuality characteristic of linen goods. The work of the stylist regarded as necessary by the delegation is of the research type and should be undertaken with some appreciation of scientific method. The subject of technical education is also one of very considerable importance. Scientific technical education has been greatly encouraged by the Textile Institute and it is expected that the policy adopted by this Institute will increase the proportion of suitably trained men in the linen and other textile industries. The training of salesmen has not been neglected by the linen trade and courses of instructions have been arranged on salesmanship and on manufacture. The problem of training young men for positions of responsibility in the industry has yet to be solved and in this the help of the Queen's University Commerce Faculty ought to be secured.

The full advantage of scientific development in the linen industry or any other industry cannot be obtained unless scientific method is used in matters beyond its control. Ten years have been spent in the scientific development of most of the industries of the country as individual units, but it has been taken for granted by those responsible that the general framework of industry was perfect before the dislocation of war A research association for the application of science to banking and exchange would appear to be necessary to train bankers to meet present-day conditions. A scientific investigation of the supply of gold in relation to the volume of transactions financed over a considerable period of years might give some indication of a way to keep the fluctuation of price measured in terms of gold within more reasonable limits. The lecturer likened the gold standard to a concertina which is pushed in and out to the accompaniment of howls of agony from capital and labour alike. The advantage to the linen trade of fitting a decimalised pound-florin currency to the dollar-cent currency by adjustment of the value of the pound was pointed out. The lecturer summed up by saying that the linen trade is now well organised for scientific development upon the technical side and that upon its administrative and commercial side it is approaching its many problems in a sensible and scientific spirit. If external economic conditions are made more favourable as a result of the efforts of the State and other outside organisations the linen trade can go forward confidently to a deserved prosperity.

A lengthy discussion followed and on the proposition of Mr. Campbell a hearty vote of thanks was passed to the lecturer.

NOTES AND NOTICES

Institute Employment Register

A list of members offering their services for employment appeared in our October issue. Further registrations have since been effected, and full particulars of qualifications and experience of candidates for posts may be obtained by interested employers on application to the Institute, quoting the registered numbers. The following announcements refer to the additional registrations—

No. 49—A.T.I., age 29, seeks appointment as Cotton Mill Manager or Assistant-Manager. Several years' experience as Head Mule and Ring Overlooker.

No. 51—Experienced Manager, age 37, 20 years' experience, winding, spooling, balling, pirning, and cop machines—for sewing yarns, etc. Technical knowledge of testing and analysis of textiles. Desires change.

No. 52—Spinning Overlooker, age 26 years, desires progressive position as Head Spinning Overlooker or Spinning Master. Mules and ring frames. All qualities from soft wefts to crêpe yarns.

No. 53—Cotton Spinning Mill Manager seeks post; 21 years' experience on the Continent. Knowledge of Russian, German, Polish, and French.

Textile Institute Diplomas

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (November issue of this *Journal*) -

FELLOWSHIP

MASON, Herbert (Dresden, Germany).

ASSOCIATESHIPS

GEE, Norman Cecil (Shipley)
WATSON, David Alexander (Paisley)
WALKER, Eric (Nottingham).
HILTON, Frank (Chorley).
PATTERSON, George Scott (Matlock)
BRUNSKILL, Joseph Haighton (Burnley).
WHITTLE, John (Bolton).
CANTRELL, Harold (Bingley).
JACKSON, Roy (Stalybridge)

Institute Membership

At the January meeting of the Council, the following were elected to Membership of the Institute—A. E. Aspinall, 4 Cumberland Street, Manchester (Textile Machinist); W. N. Bacon, Sindall & Bacon, 27 Walbrook, London E.C.4 (Consulting Chemist); S. C. Carse, 5 Ashfield Crescent, Glandore Avenue, Belfast (Linen, Dept. Manager); E. Denham, 303 Shaw Road, Oldham (Stripper and Grinder); G. Dowling, 198 Cromwell Road, Patricroft, near Manchester (Apprentice Textile Fitter); C. W. Ewing, 60 Manor Road E., Toronto, Ontario, Canada (Chemical Engineer); H. Franks, 11 Hainworth Road, Woodhouse, Keighley (Weaver's Company Scholar); H. Livingston, jun., 65 Queen Street, Lurgan, N. Ireland (Linen Factory Manager); W. A. Marsden, 12 Rydal Terrace, Jeremy Lane, Heckmondwike (Manager's Clerk, Carpet Yarn Manufacture).

Membership of the Institute

When it was decided to issue a preliminary announcement in regard to the Coming-of-Age Celebrations, it was agreed that the importance of securing a substantial increase in membership of the Institute during this particular year should be emphasised. The "Majority" year of the Institute falls at a time of great economic strain, but this circumstance only makes it the more necessary that every possible effort should be put forth to promote the advancement of

the organisation both in status and numerical strength. The fact has to be admitted and deplored that the Institute has already suffered some loss in membership as a direct result of the conditions of industrial depression, but it is nevertheless quite remarkable how the increase of membership has been maintained over many months past. At each meeting of the Council of late the list of applications for membership has been persistently extensive. The scheme of qualification of members by election to Associateship or Fellowship has produced substantial results. Whilst the continental increment of new members is satisfactory, nevertheless it is felt that at no time has the urgency for extended membership been so great as during the present year.

Coming-of-Age Celebrations

Although many members of the Institute have not, up to the time of writing, forwarded intimation as to the probability of their attendance at the Institute Coming-of-Age Celebrations (22nd to 25th April), yet the number of acknowledgments received may be said to be indicative of a satisfactory response. It is to be remembered that the circular already issued to members was only in the nature of a preliminary canvass, and it is fully expected that on the issue of the final circular a really substantial measure of acceptance will result. Approximately £40 had been received within ten days of the issue of the preliminary circular in favour of the special Celebrations Fund. The Committee is most hopeful that many members will yet assist the fund. It is hoped, indeed, that a sum of about £150 will be secured. A large number of invitations to representatives of various organisations will be necessary on an occasion of this kind, and it is in order to meet the expense of hospitality that the special fund has been opened. It has been decided not to issue any list of donations in order that members generally may be free to remit even quite small donations.

REVIEWS

The Preparation and Weaving of Artificial Silk or Rayon. By T. Woodhouse. Published by Sir Isaac Pitman & Sons Ltd. (10s. 6d. nett, 231 pages.)

The author, in his introduction, emphasises the importance of well-made knots in rayon yarn and recommends the use of mechanical knotters. It is practically impossible to produce a well-woven rayon fabric from yarns which contain a large number of badly made knots and it is fitting that this subject be introduced in the first chapter of the book. Chapter 2 deals with the reeling of yarn into hanks and also with the production of folded yarns. Chapters 3, 4, 5, and 6 are devoted to winding from hanks into various packages. Some good illustrations of the latest type of swift are introduced, followed by descriptions of modern machines for winding from hanks to bobbins, cheeses, and cones. Some 85 pages of the book are filled with information on the process of section warping and the subsequent beaming. These operations are described in detail, with calculations showing methods of dividing the warp into sections. Detailed descriptions of British and Continental machines are given with calculations on wheel gearing. Much practical information is included and this part of the book will be of interest to those actually engaged in the operation of warping. In Chapter 12, the author discusses the properties of rayon in relation to sizing and gives a general idea of the substances used. Some good micro-photographic illustrations of sized and unsized yarn are included. The various methods of sizing rayon yarns are briefly described, but a whole chapter is devoted to the process of sizing from beam to beam, this being regarded as the most important system. Three types of machine are described in detail. In the chapter on weft winding, three of the latest pirn winding machines are described. The last chapter, dealing with the actual weaving of artificial silk, is limited to 24 pages, describing briefly a few of the latest looms. These descriptions serve a useful purpose in showing on what lines these special looms are constructed. Considering the importance of weaving, the space devoted to it is small compared with, say, 85 pages on warping and beaming. The author might, with advantage, have introduced some matter on the

general principles to be observed in weaving rayon, as compared with cotton, worsted, etc. The book is well illustrated with photographs and line drawings, but it is felt that the average reader would prefer simple diagrams of machinery to intricate scale drawings, which are often difficult to follow. The machinery employed in the preparation of artificial silk yarns for warp differs from that used for cotton and as few firms engaged in the weaving of cotton and rayon fabrics possess the necessary plant, it is desirable that those engaged in the weaving of rayon should have at least a general idea of the machines and processes involved in the preparation of such yarns. This book supplies such information, its price is reasonable, and it should also be of value as a students' text book. J.S.

The Manufacture of Artificial Silk. E. Wheeler. Chapman & Hall. 2nd edition. (12s. 6d.)
In the foreword Sir Wm. H. Pope suggests that the development of artificial silk has been retarded by the meagre scope of our chemical knowledge of the various forms of cellulose and that progress has been achieved largely through means of the trial and error type. Whatever methods may have been used seem to be fully justified by the great strides which have been made in the manufacture of artificial silk during the past ten years. Artificial silk has been produced in such a degree of fineness of filament that no silkworm or spider could compete with and of such a high strength as to surpass real silk and compare with high quality steel. In the first chapter the history of artificial silk is dealt with, a short account being given of developments up to fairly recent date. Chapter II gives a concise account of the chemistry of cellulose so far as it relates to artificial silk, but contains no information of more recent date than that given in the first edition. Chapter III gives a clear but concise account of the practical methods of making viscose, with several new illustrations, and also describes methods for recovery of caustic soda by dialysing processes. Chapter IV deals with the spinning of viscose silk and describes plant and machinery employed for the purpose. The composition of spinning baths as described in a few important patents is given. Chapter V describes plant machinery and methods used for the production of ordinary grades of artificial silk from viscose. Chapter VI gives a concise account of the cuprammonium process for spinning artificial silk by the ordinary and the stretch-spinning process and gives sketches of plant used whilst Chapter VII deals with the nitrocellulose process and Chapter VIII with the wet and dry spinning of cellulose acetate silk, including illustrations of modern plant. Chapter IX gives a short account of other processes of interest but not of much practical importance. Chapter X deals with the lustre, colour, and optical properties of various kinds of fibres with various illustrations showing the cross section of fibres, including that of hollow silk. The importance of softness and suppleness is explained. A table is given showing the strength of elasticity of artificial silks, including the so-called Lilienfeld silk. The chemical properties of the various kinds of artificial silk in relation to water, alkalies, acids, and salts are enumerated and a short account of Herzog's current views on the action of water on artificial silk is given. Chapter XI deals with the dyeing of the various kinds of artificial silk in a concise manner and gives recent information published by Courtaulds on the level dyeing of viscose. Chapter XII describes the various uses to which artificial silk is put and Chapter XIII the manufacture of miscellaneous products such as staple fibre, hollow fibres, and artificial wool. Chapter XIV deals with the economies of the industry and gives statistics of production up to 1929. In the appendix useful information concerning methods of analysis is given. The new edition contains various additions to the subject matter and illustrations. A good collection of references is given, with each chapter, to the literature available on the subject of artificial silk. W.H.

Theory and Electrical Drive of the Loom. R. H. Wilmot, M.Sc., A.M.I.E.E., Assoc. A.I.E.E. Published by Sir Isaac Pitman & Sons Ltd. (144 pp. 8s. 6d.)
This book is based to a large extent on three papers published in the *Journal* of the Textile Institute for January 1928, June 1928, and October 1929, but the analysis given in these papers has been extended and completed in this book. The author claims to have developed, both mathematically and experimentally, a general mathematical theory of the loom. This is a somewhat exaggerated statement, since such important loom actions as shedding and letting-off are not considered, the book dealing only with the parts which are mainly responsible

for the consumption of power. The first six chapters are devoted to working out mathematical formulæ for the power required to drive the loom, the motions of the sley and shuttle being analysed with this end in view. The calculated time for starting up the loom and the calculated speed variation during normal running are the subjects of the next two chapters, whilst the last contains a brief description of present-day practice in the electrical drive of the loom. It is a pity that the book is marred, on the one hand, by a somewhat superficial knowledge of the loom and, on the other, by the use of incorrect assumptions and inaccurate data in the mathematical part of the work. The first is perhaps natural, since the author is an electrical engineer, but it probably leads him to consider the loom more as a machine to be driven than as one for producing cloth. He claims, for example, on page 111 that the reduced speed variation of the loom when individually driven by electric motor results in an appreciable increase in the loom output, as compared with a lineshaft driven loom. It does not necessarily follow that the loom with the lowest speed variation will have the greatest production, or turn out the best cloth. Again, it is difficult to excuse the statement on page 46, in the mathematical analysis of shuttle motion, that "the shuttle is accelerated by the pressing back of a strap at the end of the shuttle arm which is released suddenly when tight, thus catapulting the shuttle across the loom." The other fault is a more serious one. A typical example of how the author is led astray at times by wrong assumptions can be seen in Chapter III, dealing with shuttle motion. On page 54 he assumes that the acceleration of the shuttle takes place between 90 and 120 degrees after beating up. On page 58 he assumes also 30 degrees of crankshaft movement during shuttle retardation. The result is that the distances moved by the shuttle of a loom of 120 inches reed space during acceleration and retardation (Tables XX and XXII) work out to 1·898 and 1·768 feet respectively. The total length of sley, allowing for pickers, etc., would be at least 185 inches, whereas in practice the sley length would be about 172 inches only. The period of 30 degrees for acceleration is far too high for wide looms. As a result, the calculated values of shuttle acceleration are too low for wide looms and since the calculations of power for the shuttle are directly dependent on these values, the power values are inaccurate. The power for the shuttle is one of the main factors in determining the size of driving motor required and this error probably explains why the size of motor calculated by the author, 1·10 h.p. (Table XXXIII) would generally be replaced in practice (see page 126) by a motor of about 1·5 h.p.

The effect of using inaccurate dimensions and weights is seen in the calculated acceleration time for a loom in Chapter V. On page 95 the effective weight of the moving parts of a loom of 100 inches reed space is taken as 8 lb. This would be too low for a loom of only 40 inches reed space. The result is that the calculated acceleration period of 83 degrees of crank movement is certainly too low; it would probably be at least double this calculated value. The values of speed variation calculated in Chapter VI are similarly of very doubtful accuracy. It is true that the author states on page 89 that his values "do not necessarily hold good for *all* looms of the reed space given and that each specific case should be considered individually." But he does claim to have based his calculations on average plain cotton looms of average dimensions and weights of loom parts.

The mathematical part of the work is extremely well carried out, and for that reason the book is valuable. The treatment is advanced and will be beyond the scope of most students of textiles, but it should prove of use to the designers of loom motors and to loom designers. The author is on sound ground in the final chapter, dealing with the different types of motors and the methods of transmitting the power from motor to loom and it is this chapter that will appeal most to the textile reader. The book is well illustrated with diagrams, but the price seems high considering the size of the book. W.H.

Mikroskopische und machanisch-technische Textiluntersuchungen. Von P. Heermann and A. Herzog. Pp. 451, viii, 314 figures. Third edition, 1931. Julius Springer, Berlin (32 Marks).

A striking peculiarity of this book is the lack of reference to the work and publications of other countries besides Germany. This is perhaps less inconvenient to an English than to a German reader, but it has the effect of reducing the value of the book as a work of reference. The book is divided into two parts that are

so distinct that it is surprising that they should have been combined at all. Though the intention has apparently been to write a book that shall cover all the work carried out in the "physical" laboratory of a works or institution devoted to textiles, it would probably have been better to issue the book in two parts, having regard to the cost of the book as a whole. The first part of the book is similar to A. Herzog's "Die Mikroskopische Untersuchung der Seide und der Kunstseide," except that the scope is much wider, dealing as it does with all the various textile fibres. There is, nevertheless, a certain lack of balance in the treatment. For instance, much space is devoted to the embedding of fibres for section cutting, but only scant notice is given to the actual cutting operations. Yet the latter is quite as important as the former, and is never adequately treated in the current literature while embedding methods are frequently described in detail. Again the methods of top lighting which are so useful in examining the surfaces of fabrics for faults are dealt with very summarily. However, there is much useful data on the morphological and micro-chemical properties of fibres summarised in the tables, and the photomicrographs used in illustration are of the highest quality and are very well reproduced. The second part of the book deals with a miscellaneous collection of tests applicable to textiles, which can only be briefly described by an omnibus title such as that given by the authors. The subjects treated range from relative humidity measurements to periodicity determinations with the "Lunometer" and include descriptions of tensile tests, fibre diameter and staple length, fabric analysis, porosity, waterproofness, and other similar tests, together with useful diagrams and data relating to these tests. Though there is a good subject index, there is, unfortunately, no author index. However, the book can be recommended as a convenient reference work to the current German practice and literature, for many of the references are not readily accessible to English readers in the original publications, and, within its limits, the subject matter is clearly and accurately stated. J.M.P.

The Woad Plant and its Dye. By J. B. Hurry, M.A., M.D. Published by the Oxford University Press, 1930 (pp. xxviii, 328. 21s.).

The late Dr. J. B. Hurry, according to a memoir which prefaces this book, was a physician of Reading possessing wide and varied interests, amongst others, in medical and economic botany. He cultivated in his garden many plants of economic value, including the woad plant. This circumstance, combined with the fact that Dr. Hurry was also a historian and student of economics, accounts for the compilation of this work which is a study from an international point of view of the woad industry.

The woad plant as a dye is now of no practical value to dyers, although it is interesting to notice that a very small demand still exists for its use in the woad fermentation vat when dyeing indigo. Dr. Hurry, however, does not confine himself to the use of woad in dyeing, but has endeavoured to survey the subject from as many points of view as possible. He deals with the plant from its botanical aspect and in considerable detail with its cultivation and with the manufacture of the woad, whilst the woad vat and its chemistry is only dealt with briefly. The use of woad in the fine arts, in herbals, in therapeutics and the philological study of the word "woad" all have their separate chapters.

It is, however, to the economic history of the woad plant, to the laws and decrees of the ancient crafts and guilds and to the study of the conditions of trade and industry existing in the Europe of the Middle Ages that the author pays the most attention. A most interesting tale he has to tell of the rise, prosperity, and decline of a one-time great and important industry. We are shown the conditions of trade in all the chief countries of Europe, we follow the great trade routes of the Middle Ages across the Continent, study the laws, regulations, and conditions of trade of many lands for nearly two thousand years, from Cæsar's commentary on the woad stain used by the ancient Britons to Napoleon's decree that woad was to be cultivated over the whole of France.

This one time prosperous Continental industry is now but a memory kept alive by two surviving woad farms in England. There is a lesson and a warning here, for although far removed from the Middle Ages we are still governed by the continually changing conditions of progress and the birth of a new idea to-day may sound the death knell of a great industry to-morrow. L.G.L.

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PROCEEDINGS

SPECIFICATIONS FOR TEXTILE MATERIALS

By James Simpson, F.T.I.

In recent years there has been a very considerable increase in the use of specifications in the purchase of textile supplies This applies not only to those yarns and fabrics subsequently used in the manufacture of other finished products for which a rigid specification is essential but also to ordinary textile supplies The Manchester Chamber of Commerce Testing House has during the last three years prepared more than 300 specifications for various textile materials These have been prepared for Home Colonial and Foreign Government Departments Shipping Companies Corporations and other large users of textiles who whilst possibly not having a wide technical knowledge of the materials which they purchase are nevertheless desirous of standardising and maintaining the quality of their supplies Some indication of the amount of material purchased to specification may be provided by the record that during the last year fabric to the value of over £100 000 to one specification alone has been inspected at the Testing House

Manufacturers have not as a general rule welcomed working to specifications when this method of purchase is first introduced but this is probably due to their not being thoroughly conversant with the properties and performances of their own productions After working to specifications for a time preference for this form of sale almost invariably arises Manufacturers become better acquainted with the various data relating to their own supplies they realise that there is less likelihood of disputes arising and know that there is very little possibility of competitors securing business on lower quotations and supplying inferior material

In the preparation of textile specifications the first consideration should be the actual requirements of the buyer together with an appreciation of the general limitations of textile materials Such consideration will ensure calling for the most suitable and serviceable material for the particular purpose for which it is required, and also avoid calling for a material of a better quality than is necessary In the case of certain materials it will prevent the loading of the specification with unnecessary technical detail which would be likely not only to limit the sources of supply but to increase the cost of the material without any compensating gain in serviceability For example although air ship fabrics for rubberising and doping cloths for typewriter ribbons and fabrics for Swiss embroidery, are all of similar quality and structure, and would all require to be made to a very high standard as regards manufacture, their respective specifications would differ considerably Certain characteristics would be called for in the air ship fabric and others in the typewriter ribbon fabric which it would not be necessary to specify in the embroidery cloth There are also many fabrics in which it is not advisable rigidly to adhere to any particular structure as regards threads per inch, and/or counts of yarns, since different manufacturers employ different combinations of these particulars in order to produce fabrics of a similar weight and substantially of equal quality A good example of this is to be found in patent satin counterpanes in which different manufacturers produce

quilts of similar weight and serviceability, but which differ somewhat as regards the balance of threads per inch and counts of warp and weft yarns. The best procedure to adopt with such materials is to specify the weight, threads per inch and yarn counts of a particular cloth structure, but to permit alternative constructions provided the weights and qualities of the finished fabrics are substantially equal. In the case of various drills, twills, calicoes, ducks, and sheetings, even when the same number of threads per inch are used, it is not unusual to find that manufacturers work to slightly different balances of warp and weft counts. This, of course, should only be permitted so long as the material is of the required strength, and is a reasonable match for the standard sample in appearance and "handle."

All specifications should clearly indicate the methods of testing to be employed in determining their various requirements, and when necessary, the condition of the material when the determinations are made. Careful consideration should be given as to how and by whom the specifications will be interpreted and the tests applied in actual practice. When, as not infrequently happens, the testing and final adjudication is made by someone not possessing a thorough knowledge of the manufacture of the materials, it is essential that tolerances be laid down for practically every detail in the specification. In fact, generally speaking, all specifications should place a limit in at least one direction on each of the various details specified, while for some materials it is imperative that both maximum and minimum tolerances should be specified. The question of tolerances, however, demands very careful consideration, both as to what is wanted or not wanted by the user of the material, and as to the various limits imposed by the usual processes of spinning, weaving, and finishing. In specifications for either yarns or fabrics, it is advisable to refer to a standard sealed sample, since there are many characteristics such as colour, "handle," regularity, and freedom from faults, which cannot adequately be expressed in the terms of a specification.

SPECIFICATIONS FOR YARNS

The usual requirements of a yarn specification are that the material must conform to certain particulars in respect of composition and quality, moisture content, count, strength, direction of twist, number of turns per inch, and ply in the case of folded yarns.

Description, Quality, Colour, Regularity, and Freedom from Faults

The introductory clause to the specification should describe the material and call for it to be equal to a standard in respect of quality, colour, regularity, and freedom from faults. When the yarn is processed, reference will also require to be made to the finish. In order to compare the yarn from deliveries with the standard samples, the material should be wound on black boards or black cloth-covered drums.

Moisture Content

It should be specified that weights will be determined and adjusted on the recognised standard moisture "regain" basis for the material in question. It may also be necessary in certain cases, where there is a danger of mildew developing, to state that yarn which contains more than a given amount of moisture will not be accepted. The following is the method employed to determine the moisture content--

Each sample to be tested should have a weight of 1 to 1½ lbs. The sample is first weighed and is then placed in the cage of a drying oven. In the case of yarn in hank form the hanks are hung on the oven cage, but if in the form of cops, bobbins, or cheeses, the yarn should either be cut off and opened out, or reeled into hank form, to facilitate a quick and thorough drying. The drying temperature should not be lower than 212° F. and not higher than 230° F.; a suitable temperature being 220° F. The sample is weighed after it has been

in the oven for a period of 45 minutes, and subsequently at intervals of 15 minutes until the weight is found to have remained constant for three successive weighings. Samples which are known to be very damp may be left in the oven for 1 to $1\frac{1}{2}$ hours before the first oven weighing is taken. From the difference between the initial and final weighings the percentage of moisture is determined and the correct condition weight of the yarn calculated on the recognised standard "regain" basis.

Counts of Yarn

Two methods may be specified for determining the count of a yarn—

Counts in Correct-Condition—When this method is employed, the tests are carried out on the sample which was used for the moisture determination. After the sample has been weighed, it is reeled and the length measured. The sample is then dried and the bone-dry weight ascertained. To the ascertained bone-dry weight is added the standard moisture "regain," and from this correct-condition weight and the length, the correct-condition counts are calculated.

Counts after Reeling—The usual method employed to ascertain the yarn counts is to reel the material into leas or skeins on a wrap reel and to weigh them after so reeling. The yarn should be conditioned before weighing for at least six hours in an atmosphere of from 65% to 70% R.H. to ensure its containing the recognised amount of moisture. Care should be taken in reeling to ensure the yarn being kept at a uniform tension, and the wrap reel should be run at a speed of approximately 150 revolutions per minute when reeling from hanks, and 220 revolutions per minute when reeling from cops or ring tubes.

Reels should be provided with collapsible arms, so that the yarn is not strained when it is being removed from the reel. This is of particular importance, since the same leas or skeins which are used for the count determination are, in the case of cotton and woollen yarns, usually used for the strength tests. At least 10 leas or skeins should be reeled from 10 different hanks, cops, bobbins, or tubes, etc., and the weight of each lea or skein determined, first separately and then collectively, by means of a sensitive chemical balance. The count is ascertained from the total weight of the 10 leas, but the individual weighings provide a check on the results and also indicate the variation which exists from lea to lea. Count tolerances are frequently quoted in yarn specifications, and it is not unreasonable to expect cotton, woollen, and linen yarns to have an average count not varying more than $2\frac{1}{2}$% above or below the specified count.

Strength

The strength of yarns may be ascertained either by the lea or by the single thread method of testing. In both cases the yarns should be conditioned in an atmosphere of from 65% to 70% R.H. for six hours before testing, and the specification should state the type and capacity of testing machine which will be used, and the speed of traverse of the pulling jaw. The strength specified should be the minimum which will be accepted, and for this reason should not be fixed too high. In certain specifications where yarns of regular strength are required, it is not unusual to find the strength regularity specified. This is obtained from the single thread strength results, the difference between the mean strength and the sub-mean strength being expressed as a percentage of the mean.

Direction of Twist

The direction of twist should be specified, and so that standard terms can be applied in all yarn specifications, it is advisable to describe the twist as "right-hand" or "left-hand" rather than "twist-way" and "weft-way," as is the general practice in the case of cotton yarns. In a "right-hand" twist, the yarn when held vertically shows the spirals or twists to incline upwards in a right-hand direction, and in a "left-hand" twist the spirals or twists are seen to incline upwards in a left-hand direction.

Turns per Inch

In testing the turns per inch in a single yarn each of the 10 hanks or cops, etc., from which the counts and strength tests have been made, should be tested on one inch lengths of yarn. At least five tests should be made from each sample, making a total of at least 50 tests. In the case of folded yarns, it is usual to carry out the tests on 10 inch lengths of yarn, and at least 20 tests should be made.

Other Special Requirements

It is necessary in the case of certain yarns to call for such special requirements as the "percentage of the mixture" in union yarns, "freedom from, or percentage of foreign matter or grease," and "the fastness of dyes." Since the methods of making these determinations are the same for yarns as for fabrics, they can be considered in detail when dealing with specifications for fabrics.

SPECIFICATIONS FOR WOVEN FABRICS

Specifications for woven fabrics should call for a material to conform in certain respects to all or a number of the requirements detailed below.

Quality, Texture, Colour, Design, and Finish

The first requirements of a fabric specification should be that the material be equal to a standard sample in respect of quality and texture, and, when necessary, as regards colour, design, and finish.

Composition

The composition should be specified, particularly when union materials are called for. When the composition of the warp yarn differs from that of the weft yarn, this should be clearly stated. The usual chemical, microscopical, and dissection methods should be employed to determine the composition

Width

For certain materials a minimum width must be called for, whereas for others an average width with a maximum and minimum tolerance may be specified It should be possible in the manufacture of most fabrics to work to a tolerance of 1·5% above or below a specified width. The average width of a piece should be determined by measuring in at least five different places throughout the length Each measurement should be made with the material laid flat on a table with the tension released.

Length

It is frequently necessary to state the minimum length of pieces to be supplied, since short pieces are often uneconomical where the fabric is to be used as a component part in other products. The most satisfactory method of ascertaining length is to measure the pieces by pulling them over a 4 or 5 yard table.

Weight

The specification should either give a minimum weight or specify an average, with a maximum and minimum tolerance. Although, generally, a buyer will not object to extra weight, there are some materials in which strong exception is taken to a too heavy fabric. The weights should ordinarily be determined from the weight, length, and width of at least 10% of the pieces. In cases of dispute, samples should be tested for moisture, and the weight adjusted on the recognised standard moisture "regain" basis. With regard to tolerances to be permitted, this depends upon the type of material, and also as to whether it is a loom-state or finished fabric. It is considered, however, that even in the most variable material, the tolerance in weight below that specified should not exceed 5%, and in many fabrics should not exceed 3 per cent.

Foreign Matter, Dressing, or Filling

. The amount of foreign matter should be specified, but unless a pure finish is required, a fairly considerable tolerance may be allowed in this respect, provided the finish and "handle," when of importance, and the pure weight are

satisfactory. The usual method employed to ascertain the amount of foreign matter present in a material is by repeatedly boiling the sample in water until all the foreign matter is removed. It is sometimes necessary, particularly in the case of bleached or filled fabrics, to add some substance like diastafor to facilitate the solution of the starch. The sample is weighed in a bone-dry condition, before and after removal of the foreign matter.

Grease

In certain woollen fabrics it is necessary to specify the maximum grease content; the amount of grease present in the material being determined by means of an ether extraction.

Threads per Inch

The threads per inch in a fabric should be specified either as a minimum or with a plus and minus tolerance. The extent of the tolerances will again depend on the class of fabric, and also as to whether it is a loom-state or a finished material. It is, however, not unreasonable for the average run of fabrics to permit a tolerance below that specified of not more than 3% for warp threads and 5% for weft threads. The threads per inch should be ascertained from the count of at least 10% of the pieces in a delivery, and each piece should be counted in at least ten different places in both the warp and the weft direction. No weft countings should be made at a less distance than 2 yards from the end of a piece, or warp countings at less than 2 inches from the selvedges. In counting the threads per inch, the actual number of threads and parts of a thread per inch should be counted as such, so that, in the case of the warp, the ascertained threads per inch multiplied by the width of the cloth will give as nearly as possible the total number of ends in the warp. It is necessary to emphasise this, since other methods are sometimes employed. In one of these, each thread or part of a thread which can be seen when a one inch glass is placed on the cloth is counted as one thread, and by another method only whole threads are counted and part threads ignored. The ordinary one-inch glass should be quite satisfactory for the counting of the general run of fabrics, but for very open fabrics it is sometimes desirable to count the threads per three inches.

Thickness

For many fabrics which are to be used for rubberising, for filter cloths, and for other mechanical purposes, a thickness is specified. When this is done, the type of micrometer which is used should be specified, since very different results are obtained with different instruments. The load under which the measurement is made, and the size of the micrometer discs in contact with the fabric are the two important factors.

Counts of Yarn

It is not the usual practice to specify the counts of the yarns in fabric specifications, since, generally, materials of substantially similar texture can be obtained from a specified weight, percentage of foreign matter, threads per inch, and strength. There are, however, certain purposes for which exceptionally uniform fabrics are required, and for which the counts of the yarns must be specified. This is also the case for certain compound fabrics where a particular balance of texture must be preserved. Such fabrics are generally cotton fabrics, and in considering the method of testing, only cotton fabrics will be dealt with. When ascertaining the counts of yarn from a cloth, even if the count of weft only is required, the sample should be thoroughly washed to remove all size. This is obviously necessary in the case of materials which have been piece-filled, but it may not be quite clear as to why it should be done in the case of nominally pure fabrics. The reason is that only by analysis can it be ascertained whether the cloths contain any substance which might give fictitious weight to the yarns. For instance, chloride of magnesium may have been used in sizing the warps,

even without the knowledge of the sizer, who unwittingly may have bought it disguised as a size composition. Should this be so, a fair proportion must spread to the weft by absorption, carrying with it, or taking from the air, enough moisture to destroy the accuracy of the test. As a result of experiments made at the Testing House, it has been found that grey cotton material, when pure, loses on the average approximately 2% of its weight when washed. It is therefore the general practice to add 2% to the weight of yarn taken from washed grey cotton fabric to compensate for this loss in washing.

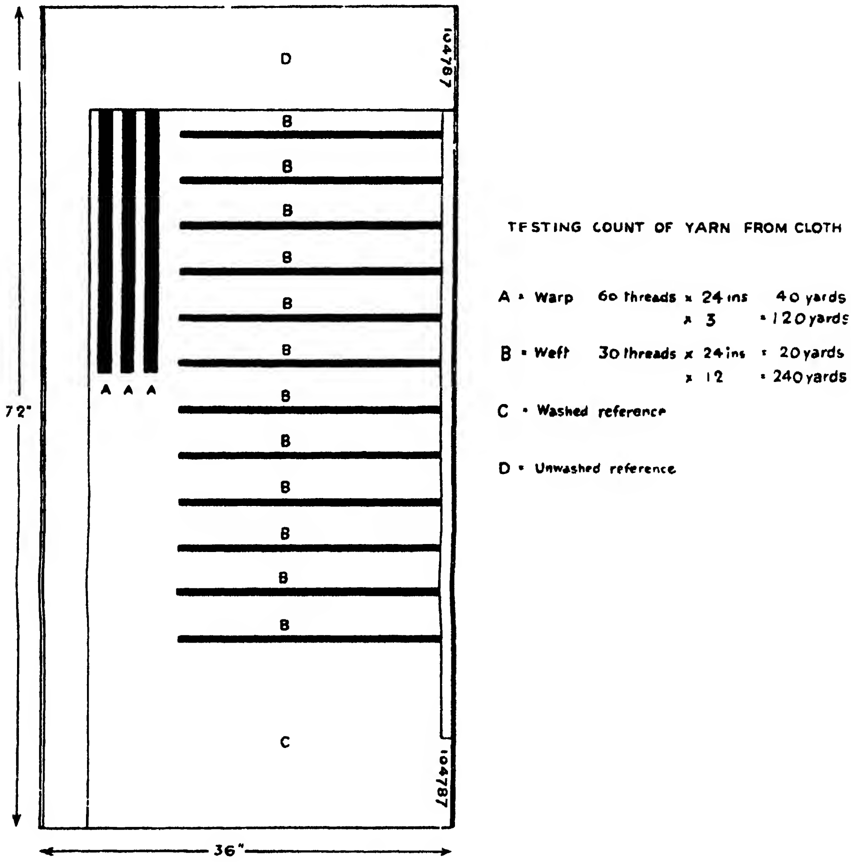


FIG. 1

After washing, the samples are dried slowly at a temperature of 70° to 80° F., and after drying they are allowed to condition for at least six hours in an atmosphere of from 65% to 70% R H. When the conditioning has been completed, the warp and weft yarns are taken from the sample, accurately measured for length, and weight. This is done by first measuring and then cutting convenient lengths of cloth from the sample in both the warp and weft directions, and taking out several lots of threads from each length. Each length of cloth is cut as far away from the next as the size of sample will permit. For convenience in calculation, the length of cloth is cut so that when the yarn to be tested is removed it will have a length of a multiple of 36 inches. The length is taken after the crimp has been removed, and the yarn held at a tension which is judged to be similar to that at which the warp yarn would be during weaving. Each lot of warp and weft is then weighed, first separately, and then collectively,

by means of a sensitive chemical balance The counts of the warp and weft are calculated from the total length and weight of warp and weft yarn removed They are also determined from the individual weighings of each lot of yarn, and by this means provide a check on the count as obtained for the total weight of warp and weft yarn As a final check on the counts, the pure weight of the material may be calculated from the ascertained threads per inch counts of yarn and crimp, and compared with the determined pure weight of the material

Fig 1 shows in detail how a sample of cloth, 36 inches wide by 72 inches long should be dealt with in testing the counts of warp and weft The sample is first marked with its test number and a portion cut from it and retained for reference purposes The remainder is then washed dried and conditioned Three lots of warp, each containing 60 threads 24 inches long and twelve lots of weft each containing 30 threads 24 inches long are removed from the conditioned pattern Each of the three lots of warp and the twelve lots of weft are weighed separately and together and the counts ascertained As a rough check, 20 threads of warp and 20 threads of weft should be taken from the sample and weighed by an independent observer It will be noted that the total length of yarn tested is equal to 1 lea of warp and 2 leas of weft It has been found necessary to test this amount of yarn in order to obtain reliable results The methods of testing for counts in which templates and quadrant balances are used do not as a rule provide accurate results The lengths of yarn tested are generally too short having regard to the normal variation in the yarn and further many of the quadrant balances are not sufficiently sensitive

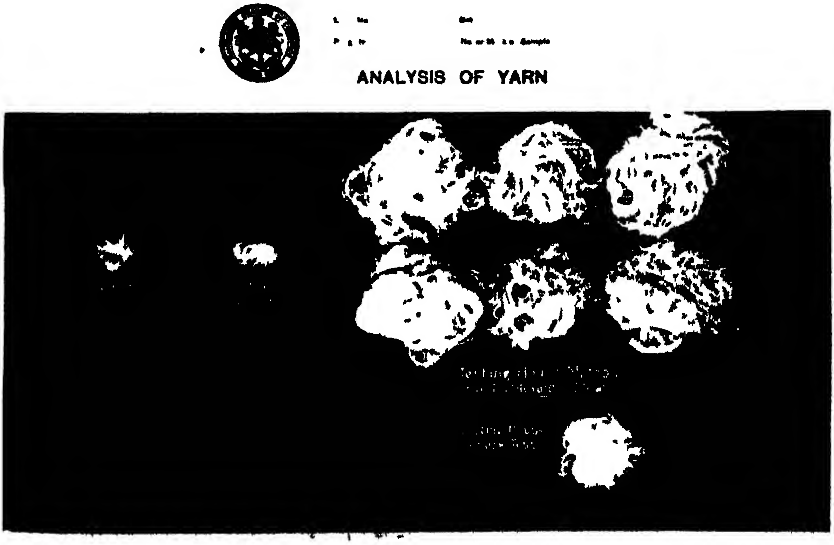


Fig 2

Fig 2 shows the amount of weft yarn which would be used in the method of testing which has been described, together with the amount used in two of the template and quadrant balance methods It will be seen that the amount of yarn used for the rough check tests in the method described exceeds that used in either of the two template methods

Table I

COUNTS OF YARN AS ASCERTAINED FROM TESTS ON CLOTH

Comparison of Testing House method with two methods commonly employed in the trade referred to as Method "A" and Method "B."

The material employed for the comparative test was a 5 yard length of grey cloth of the nominal particulars "80 × 128 38's 32's"

	Method "A"	Method "B"	Testing House Method
Size of test piece	Template 2·4 in	Template 3·6 in	2 yds regulation size
Length of yarn weighed	40 threads × 2·4 in 2⅔ yds	40 threads × 3·6 in 4 yds	*Warp*– 3 tests of 40 yds 120 yds *Weft* 6 tests of 40 yds 240 yds

In order to demonstrate the variation commonly found on such short lengths of yarn as those used in Methods "A" and "B," 25 tests of the warp and 50 tests of the weft were made The following are the detailed results of these tests in comparison with the Testing House results —

	Count	Count	Count	Count	Count
Warp. 25 tests	35·2	38·2	35·3	37·2	
	36·2	38·2	35·9	37·8	
	37·1	39·2	35·9	37·8	37·1
	37·1	39·2	35·9	37·8	38·0
	37·1	39·2	35·9	37·8	38·0
	37·1	39·2	36·5	37·8	
	37·1	39·2	36·5	37·8	37·5
	38·2	39·2	36·5	37·8	
	38·2	40·3	36·5	37·8	Count of 1 lea
	38·2	40·3	36·5	38·5	result certified
	38·2	40·3	37·2	38·5	
	38·2	40·3	37·2	39·2	
	38·2		37·2		
Warp variation	35·2 to 40·3		35·3 to 39·2		
Weft. 50 tests	32·8	35·2	30·2	34·2	
	32·8	35·2	30·7	34·2	
	32·8	35·2	30·7	34·2	
	32·8	35·2	30·7	34·2	
	32·8	35·2	30·7	34·2	
	33·6	36·2	31·1	34·2	
	33·6	36·2	31·6	34·7	
	33·6	36·2	32·1	34·7	33·0
	33·6	36·2	32·1	34·7	33·7
	33·6	36·2	32·6	35·3	33·7
	33·6	36·2	32·6	35·3	33·7
	33·6	36·2	32·6	35·3	34·8
	33·6	36·2	32·6	35·9	35·5
	33·6	36·2	33·1	35·9	
	34·4	36·2	33·1	35·9	34·0
	34·4	36·2	33·1	35·9	
	34·4	36·2	33·1	37·8	Count of 2 leas
	34·4	36·2	33·1	37·8	result certified
	34·4	37·1	33·1	37·8	
	34·4	37·1	33·6	37·8	
	34·4	37·1	33·6	37·8	
	35·2	37·1	33·6	37·8	
	35·2	37·1	33·6	38·5	
	35·2	37·1	33·6	38·5	
	35·2	38·2	34·2	39·2	
Weft variation	32·8 to 38·2		30·2 to 39·2		

The figures in Table I are the actual results of tests on yarns taken from the same sample of cloth and show the very variable results any one of which it is possible to obtain by the template methods of testing

Strength and Elongation

In most loom state and in all finished fabrics strength and elongation tests should be specified not because the strength of a material is in itself always an important factor but because the strength will generally indicate the quality of a material its serviceability and show whether finished materials have been excessively weakened in the finishing processes The strength specified should be a minimum, and since it is possible in many cases to over emphasise the importance of such tests care should be exercised not to call for too high strengths Regard should be paid to the strength it is possible to obtain from any particular structure of fabric, the variation which is found to exist even in different specimens from the same piece and the actual requirements of the material for the purpose for which it is to be used

In order to obtain constant moisture conditions in the samples at the time of testing the specification should state the condition of samples when the tests are made The usual method is to test after exposure for a certain period at from 65 % to 70 % R H but in certain materials the desired constant condition may be obtained by testing either in a wet or in a bone dry condition

The specification should also state the type of testing machine its capacity and the speed of traverse of the pulling jaw or the rate of loading when a constant rate of loading machine is used

The size of specimens to be tested should be stated and also the method of their preparation In most materials the specimens have to be prepared by fraying down from samples of a wider width but other materials have to be cut exactly to the required width since they cannot be frayed In deciding the width to be frayed care should be taken to make it large enough to ensure that in testing the outside threads of specimen will take their full share of the load

Generally six warp and six weft specimens will be tested from each sample and Fig 3 shows how the specimens should be cut so as to ensure that the result obtained will be fully representative of the sample tested

Fastness of Dyestuffs

Specifications for coloured fabrics should call for the material to satisfy certain requirements in respect of the fastness of the dyes used to light rubbing washing and perspiration In judging the fastness of dyes to certain treatments the following classification is frequently adopted

- A Fast (no appreciable change)
- B Commercially fast (changes shade slightly)
- C Changes shade moderately
- D Changes shade considerably

Generally all materials which can be classified as either A or B will be satisfactory and except in the case of poor quality fabrics any material classified as C or D would be considered for rejection Tests for fastness to light can be standardised and tested according to the requirements of the material by means of artificial sunlight lamps such as the Fade ometer or the Fugitometer Resistances of the dye to rubbing can be tested by rubbing a sample on a piece of bleached cotton In ascertaining the fastness of a dye to washing tests should be made in order to determine how the shade changes when a sample is steeped —

(*a*) In boiling water for five minutes

(*b*) In a 2 % boiling soda solution for five minutes

(*c*) In a 2° boiling soap solution for five minutes

Tests should also be made by subjecting a sample to an actual washing in hot water and soap In this test, in order to eliminate differences due to the human factor it is advisable to make the tests in some mechanical washer in which

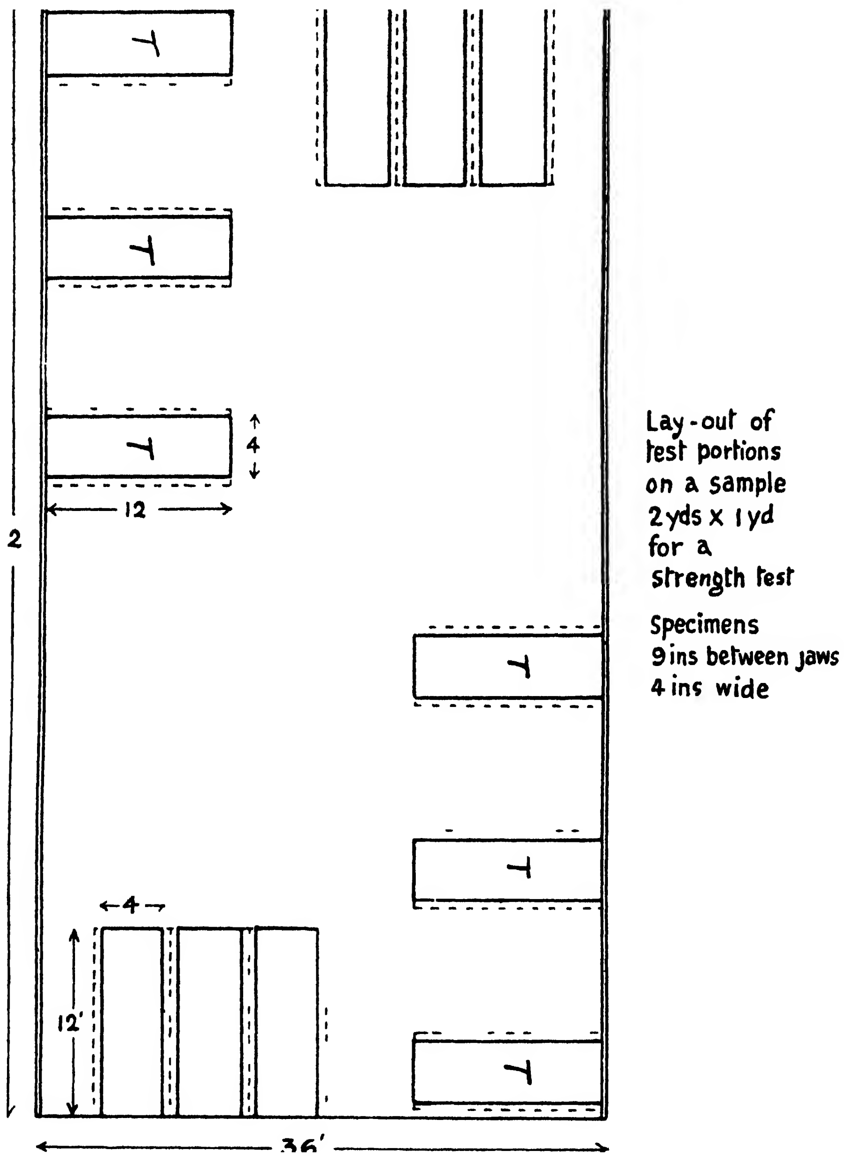


FIG 3

the treatment can be standardised To test the resistance to perspiration, samples of the material should be subjected to both an acid and an alkaline test A cutting of the fabric is rolled together with a cutting of bleached cotton,

and one of white woollen material. These are then soaked in a solution consisting of 1 litre of water, 100 grammes of sodium chloride, and 50 grammes of acetic acid. After soaking, the rolled cuttings are left to dry for 24 hours at a temperature of 40° C., and then examined in order to see if the colour has marked-off on to the cotton and woollen materials. A similar test is made after soaking in an alkaline solution consisting of 1 litre of water, 100 grammes of sodium chloride, and 10 c.c. of ammonium hydrate of sp. g. 0·88.

Shrinkage

The extent to which a fabric will shrink, due to wetting or washing, is in many materials an important factor, and tests for shrinkage should be included where necessary in fabric specifications. Here again, care must be exercised to avoid calling for an impossible performance. It is sometimes more economical to make garments on the large side to allow for the shrinkage which will take place during the first few washings than to insist on the material being supplied with a low shrinkage. The latter may necessitate an extra finishing process and thereby increase the cost of the material. A method of determining the shrinkage is to soak a sample of the material for two hours in cold water and then allow to dry, laid out on a flat surface, at a temperature of 60° to 70° F. A suitable size of specimen is 15 inches wide by 10 inches long. The sample should be cut larger than the 15 inches by 10 inches, and the rectangle formed by these dimensions should be marked-off and carefully stitched with a coloured sewing thread. By this method of marking, the measuring of the sample after soaking and drying is greatly facilitated. When a more severe test than soaking is necessary, the material may be tested by washing in hot water and soap. The same mechanical washer used for testing the fastness of dyes to hand-wash may be used for this test.

Manufacture

For very high-class fabrics which can be woven practically perfect, it is possible to specify that the material shall be free from all faults of manufacture, or that allowances in length will require to be made when the fabrics contain particular faults. It is an extremely difficult matter, however, to lay down in the terms of a specification, requirements as to manufacture for the average run of fabrics. In certain specifications, such as those for aircraft fabrics, various faults may be enumerated and described. The faults may then be classified as minor and major faults, and a limit placed on the number of such faults which any piece of material may contain. The distribution of the defects, however, is a feature which it is somewhat difficult to describe in the terms of a specification, and unless there are particularly good reasons for it, the general adoption of this procedure is not to be recommended. It is probably sufficient in the general run of fabrics to specify and, if necessary, describe the defects which are most objectionable from the user's point of view. In this connection I have in mind faults, such as uneven selvedges, badly bowed weft, distorted weft, and broken patterns which may be particularly objectionable and which would be likely to result in considerable wastage of material in actual use.

Special Requirements

In addition to the specified details which have been enumerated, certain types of fabric may be required to satisfy other tests. Fabrics which are to be subjected to the action of heat, for example, may be required to be free from chlorides, the presence of which would be likely to cause tendering of the material on heating. Scoured fabrics for rubberising and other purposes may be required to be free from acidity and alkalinity, when spotted with suitable indicators. Fabrics to be used in the manufacture of outer garments which are to be shower-proof may be subjected to a shower-proof test. In this test, water is permitted to drop on a sample of the cloth for a period of 1½ hours, falling from a height

of 6 feet at the rate of 16 drops per minute, when no trace of moisture should have penetrated to the underside of the material. Specifications for heavily proofed canvas for use as tarpaulin covers may call for a material to satisfy more severe water-tightness tests, such as the cone and pressure tests. In the former test, a sample of the fabric, 10 inches square, is folded like a filter paper and placed in a glass funnel, where it is loaded with 500 ml. of water. No water should have penetrated to the underside of the fabric after a period of 24 hours.

In the pressure test, a disc of the material of 12 square inches is subjected to a specified water pressure for a specified time, when no percolation must occur. In this test the pressure and time specified are factors which vary according to the type of material.

TYPES OF SPECIFICATIONS

Tables II, III and IV which conclude this article are typical specifications chosen from the many available to illustrate the main points discussed in the foregoing paragraphs. The first, Table II, is a specification for an ordinary grey cotton twill sheeting. The next, Table III, is a specification for a cotton bath mat for which, being a compound fabric, it is necessary to specify the counts of the various yarns used. The third, Table IV, is typical of specifications issued by rubber manufactures for materials required to be exceptionally uniform. In this only the test requirements have been given, but the complete specification actually includes, and describes fully, the method to be employed in carrying out each of the tests. The specimens used for the strength tests on this material would not actually be measured to a one inch width but would be frayed down until they contained the specified number of threads per inch.

Textile specifications as generally issued to-day are far from being perfect, and even the best of them can be improved. Suggestions from suppliers, users, or others interested will help in this direction.

It has not been the intention of this paper to state the practice which should be followed in the preparation of textile specifications, but rather to indicate the general commercial practice which is followed to-day, and which has generally been found to work to the satisfaction of both the supplier and the user

Table II

Specification for Grey Cotton Twill Sheeting

Quality, Texture and Colour	To be similar to the sealed sample in respect of quality, texture and colour
Width	Not to be less than 70 inches
Length	To be supplied in pieces of not less than 60 yards.
Weight	Not to be less than 14¼ oz per lineal yard.
Foreign Matter . . .	To contain not more than 10% of foreign matter
Threads per inch . . .	Warp 60, Weft 64.
Strength	The mean breaking load of the fabric shall not be less than 125 lb. and 185 lb. in the warp and weft directions respectively, when tested in the following manner – Six specimens shall be cut in the direction of the warp and six in the direction of the weft The size of specimens shall be 2 in wide and 7 in between the jaws of the testing machine. The tests shall be made on a Goodbrand machine, the travelling jaw of which has a constant rate of traverse of 18 in. per minute. Before testing, the specimens shall be exposed for at least six hours in an atmosphere of 65 to 70% relative humidity.

Table III

Specification for Cotton Bath Mat

Quality, Texture, Design, Shade, Finish and Make	To be similar to the sealed sample in respect of quality, texture, design, shade, finish and make. To be lettered A B C in the centre similar to the standard
Width	Not to be less than 20 inches
Length	Not to be less than 31½ inches before hemming and 30 inches after hemming
Weight	Not to be less than 12 oz per mat
Threads per inch	Warp 44 (2 terry, 2 ground) Weft 65
Counts of Yarn (in finished state after washing)	Warp: ground 3/32s, terry 3/12s; Weft 16s
Class of Dye	Turkey Red
Fastness of Dye	The dye of the material to be commercially fast when washed by hand in hot water and soap
Terry	The terry portion of the mats to contain not less than 5½ yards of pile warp per yard of ground warp

Table IV

Specification for Cotton Canvas

Quality, Texture, Colour and Finish	To be similar to the sealed sample in respect of quality, texture, colour and finish
Composition	The yarn shall be spun from a well carded cotton and the average length of staple shall be ⅞ inch
Width	56 inches 0.25
Length	160 yards 5 yard
Weight	14 oz per square yard 3 per cent
Threads per inch	Warp 21 0.4 Weft 22 0.9
Thickness	0.037 inch 0.002 inch
Count of Yarn	Warp 3.7s Weft 3.7s
Folded Twist per inch	Warp 6.9 0.75 Weft 5.0 0.75
Crimp	Warp 16% 2% Weft 8% 2%
Strength (12 in. × 1 in.)	Not to be less than Warp 140 lb Weft 175 lb

NOTES AND NOTICES

Institute Coming-of-Age Celebrations

An outline of the programme of the Coming-of-Age Celebrations of the Institute—at Manchester on the 22nd, 23rd, and 24th April— has been issued to members, together with form of attendance to indicate participation in the various events. Although the closing date for receipt of acceptances has been fixed for the 10th April, members are urged to send in completed forms as early as possible in order to facilitate arrangements generally. The prospects are that there will be a big attendance. The President (Lieut -Col. B. Palin Dobson) and the Chairman of Council (Mr. F Nasmith) are taking an enthusiastic interest in the whole event. It is hoped that Lord Derby, who has expressed his interest in the Coming-of-Age Celebrations, may be able to attend and speak at the banquet. Lord Barnby has already notified acceptance and also his preparedness to respond to the toast of "The Textile Industries" Sir Percy Jackson (Chairman of the West Riding Education Committee) has kindly consented to propose the toast of "The Textile Institute," whilst Dr. R. H. Pickard (Director of the British Cotton Industry Research Association) has agreed to propose the toast of "Our Guests." The complete programme will be sent to all who notify attendance. The proceedings will be opened by a Reception on the part of the President and Council of the Institute, and complimentary invitations for this event have been sent to members. All meetings and functions, with the exception of the Public Lecture by Sir Leonard Hill on the Friday evening, will take place at the Midland Hotel, Manchester. In the course of the proceedings, the presentation will take place of a number of medals, including the new Warner Memorial Medal (for "investigations in textile technology" published in the *Journal* of the Institute), and the Institute Medal (for "services to the Institute") It is also expected that an Honorary Fellowship of the Institute will be bestowed

Annual General Meeting

The holding of the Annual General Meeting of Members of the Institute, will not take place at so early a date as usual this year, owing to the holding of the Coming-of-Age Celebrations in April. The date fixed for the Annual Meeting for the election of Officers and the approval of Council's Report, Balance Sheet, and the Accounts (with reports of Auditors), is Wednesday, 20th May, at 4 p.m. The date and time have been selected for the reason that the Council will meet on the same afternoon, and the arrangement will assure a representative gathering Mr. George Garnett, of Bradford, who has been a steadfast supporter of the Institute over many years, is nominated for election as the next President. It is particularly desired that members of Council shall have the best opportunity to attend the Annual Meeting, and to support the nomination. With regard to the annual election of members of Council, nomination forms have been issued to Members, and the reminder may here be made that the last date for receipt of nominations is 13th April.

Institute Membership

At the February meeting of the Council, the following were elected to Membership of the Institute —J. G. Bekker, Veterinary Research Laboratories, Onderstepoort, Pretoria, S. Africa; T. Butterworth, 79 Park View Terrace, Preston Old Road, Blackburn (Under Carder); A .E. Inglis, Tramore, Kinders Lane, Greenfield, near Oldham (Salesman, Asa Lees & Co. Ltd., Oldham); V. P. Iyer, The New Ginning, Pressing & Manufacturing Co. Ltd., Chalisgaon, E.K., India (Spinning Master); N. J. Levy, 38a Clyde Road, West Didsbury, Manchester (Foreign Correspondent and Salesman); A. W. W. Lynch, 23 Hartington Road, Sherwood, Nottingham (Student); F. C Nightingale, Thomas Cross & Co. Ltd , Mortfield

Bleach Works, Bolton (Departmental Manager); J. W. Polito, 23 Hartington Road, Sherwood, Nottingham (Student); R. T. Read, 21 Garthwaite Avenue, Coppice, Oldham (Trainee, Lancashire Cotton Corporation); C. F. Reed, 68 Sprules Road, Brockley, London, S.E.4 (Advertising Manager, Pawsons & Leafs Ltd., 9 St. Paul's Churchyard, London, E.C.4); I. E. Weber, B. Laporte Ltd., Chemical Manufacturers, Luton, Beds. (Director and Chief Chemist); H. G. Wolstenholme, 34 Belfield Road, Didsbury, Manchester (Cotton Yarn Salesman); R. Wood, 557 Cleckheaton Road, Low Moor, Bradford (Cloth Checker).

COMMUNICATIONS

"Theory and Electrical Drive of the Loom"

To the Editor

Sir,—Several statements which appear in the review of "Theory and Electrical Drive of the Loom" published in the *Journal of the Textile Institute*, February 1931, pp. P18–P19, the author feels obliged to challenge and correct. In view of these criticisms it is thought that the book should have been particularly useful since it gives information which has been based on a series of experimental investigations and on actual data from practical experience extending over a number of years. It has remained to an electrical engineer to do this as the data supplied by loom authorities in most instances has been unreliable and incomplete.

Shedding and let-off motions were not analysed in detail for the reasons set out in page 6. The statement "incorrect assumptions and inaccurate data" is a very misguided one. The whole of the mathematical work (as pointed out in several places in the book) is based on actual experimental tests and observations. For example, it was proved conclusively in connection with a particular 120 in. plain loom that the acceleration period of the shuttle corresponded to 34 degrees and that the measured values of the power were very close indeed to those calculated for the particular loom, *e.g.* a test lasting 38 hours on a 120 in. plain cotton loom showed an average figure of 1·16 h.p. as against a calculated value of 1·10 h p. (Table XXXIII). The h.p figures of the example given in page 126 are on the high side but these looms were installed many years before the above tests were made and were based on loom makers' data.

The accuracy of the acceleration and normal running calculations (Chapters V and VI) has been questioned. At the time of writing the book these calculations had not been compared experimentally with practical results, but quite recently a number of tests carried out using an oscillograph connected in the driving motor circuit showed conclusively that the experimental and calculated acceleration times and speed variations during normal running agreed very closely.

Humberstone, Leicester, (Signed) W. H. WILMOT.
2/3/1931.

Reviewer's Reply

Sir,—The reasons given by Mr. Wilmot on page 6 of his book for the omission of a consideration of some of the most important parts of the loom, can hardly be held to justify his claim in the preface, that he has developed a *general* mathematical theory of the loom.

Although it may have been proved conclusively in connection with a particular 120 in. plain loom that the acceleration period of the shuttle was 34 degrees, the fact remains that the slay must have been about one foot longer than usual, and that the loom, in consequence, did not represent *average* practice, as claimed by the author.

The power test average figure of 1·16 h.p. does not appear to agree with the

calculated value (Table XXXIII) of 0·80 h.p., the value of 1·10 h.p. quoted by the author being the root mean square value.

The accuracy of the acceleration and normal running calculations was not questioned; it was the accuracy of the data on which the calculated values depend that was, and still is, claimed to be doubtful.

The statement "incorrect assumptions and inaccurate data" is a strong one, but the examples given in the review were not isolated examples.

W. A. H.

REVIEWS

English Decorative Textiles: Tapestry and Chintz; Their Design and Development from the Earliest Times to the Nineteenth Century. By W. Gordon Hunter. Published by John Tiranti & Co., London, W.1. (8 pp., 181 plates, price £2 10s.)

Taking into account the fact that this country possesses no national style of design the author has collected 180 or more historical examples which are particularly interesting on account of their very varied characteristics. The tapestries give a valuable lesson on the treatment of design of various periods and show the influence of great artists of their time upon the craft of weaving. A set of six panels entitled the "Parable of the Prodigal Son" produced at the Sheldon Tapestry works in the second half of the 16th century in spite of their ornate borders are examples of skilful composition, sympathetic treatment, and marvellous weaving. The Mortlake Tapestries, and several outstanding treasures of the Victoria and Albert Museum are well chosen illustrations.

The latter half of the book deals with printed fabrics. Plate 85 is a delightful example of the best period of English naturalistic design in the latter part of the 18th century when attractive chintzes and glazed prints were produced which were so delicate and free in treatment. Compare this with Plate 126, an early 19th century production showing a composite capital complete with bouquet of flowers and birds—interesting as a link in the evolution of styles, but the very worst type of design for the material. Possibly the prevailing taste for this type of ornament led Ruskin, Morris, and other 19th century reformers of the pre-Raphaelite period to strive for a revival of the better traditions of the past and to recognise the value of simple flat treatments, good compositions with refinement of drawing. Nine examples of William Morris block prints produced at Merton Abbey are shown. Whilst the mechanical processes involved have altered very little in detail and not at all in principle a great advance has certainly been made in the artistic value of printed fabrics. It must be admitted that 20th century design, full of sparkle and vitality in both form and colour, is a living style and not merely the natural evolution from styles of the past.

It is unfortunate that the text matter has been condensed into eight pages. A fuller description of the plates regarding colour and the sizes of the original would have helped the reader whilst a few coloured plates would have added enormously to the attraction of the book, even if it meant leaving out some of the half-tone reproductions of richly coloured materials which suffer so much by translation into black and white.

E.R.D.

THE JOURNAL OF THE TEXTILE INSTITUTE

Vol. XXII APRIL 1931 No. 4

PROCEEDINGS

NOTES AND NOTICES

Institute's Coming-of-Age

Our record of the proceedings in connection with the Coming-of-Age Celebrations will appear in the May issue of the *Journal*. At the time of writing, there appears every prospect of a successful and memorable gathering, and every possible effort had been made to ensure satisfactory arrangements. Both the President and Chairman of Council took the utmost interest in the whole fixture, and were unremitting in their efforts. On every hand, appreciation of the importance of the occasion was most encouraging. The inclusion of broadcasting of speeches at the Banquet, by arrangement with the B.B.C., represented an outstanding instance of recognition of the Institute's influence. The distribution of honours awarded by the Council of the Institute met with widespread appreciation and it was generally recognised that selection of the recipients had been carried out with most appropriate results. In the case of the six medals awarded for services to the Institute over the twenty-one years, it was remarkable that, with one exception, every recipient had continued to serve in membership of the Council for the entire period. It was most fitting that on this occasion the first presentation of the medal to perpetuate the memory of the late Sir Frank Warner should have taken place, for it was largely due to his untiring zeal in the early and struggling days of the organisation that the Institute was permitted to go forward in development. Notwithstanding all the progress effected in the last twenty-one years, it is hoped that still further progress will be attained. The proceedings in connection with the majority celebrations should provide not only a stimulus to those now participating in the efforts of the Institute, but an inducement to many individuals to join in the movement.

Annual General Meeting

The Annual General Meeting of the Institute is to take place on Wednesday, 20th May, at headquarters. The Council will meet on the date named at 3 p.m. and the Annual General Meeting will follow when one of the most interesting items will be the election of President for the ensuing year. Mr. George Garnett, of Bradford, who has for so many years been a keen supporter of the Institute, has kindly accepted nomination for the Presidency, and it is therefore hoped that Yorkshire members, in particular, will attend this meeting and support the election of the new President. The election of Council will take place. Nomination forms were issued recently in connection with this event and there are eighteen candidates for the ten vacant seats. The Council's Annual Report with Balance Sheet and Accounts are in course of issue; Ballot Papers are also prepared. In regard to Vice-Presidents, there are three retirements due this year but the Council has renominated Messrs. A. F. Barker and W. Frost. Anticipating the election of Mr. George Garnett to the Presidency, only one other nomination is required, and the Council decided to nominate Professor E. Midgley, of Bradford, for the third Vice-Presidential place.

Midlands Section Annual Meeting

The Annual Meeting of the Midlands Section is fixed to take place on Saturday, 16th May, at University College (Shakespeare Street), Nottingham. In addition to the ordinary business to be transacted, Mr. J. H. Lester, M.Sc., has kindly promised to attend and give an address on "Past, Present, and Future of the Textile Institute." Mr. S. E. Ward, of Nottingham, has kindly invited members in attendance to take tea immediately after the meeting. The election of the Section Committee will form one of the chief items of the Agenda.

Death of a Lancashire Machinist

Mr. W. B. Richardson, whose death took place quite recently at his residence at Rivington, near Bolton, was a well-known Lancashire textile engineer who for many years had been a keen supporter of the work of this Institute. He gave excellent service on several committees for several years past, and attended many of the Conferences of the organisation. Mr. Richardson was a member of the Council of the Federation of British Industries, and was interested in local government affairs. Mr. John Crompton attended the funeral as representing the Council of the Institute.

Textile Institute Diplomas

Elections to Fellowship and Associateship have been completed as follows since the appearance of the previous list (February issue of this *Journal*)—

FELLOWSHIPS

CHADWICK, Frank Teasdale (Leeds).
STRONG, John Henry (Blackburn).
SCHOLEFIELD, Fred (Manchester).

ASSOCIATESHIPS

ASHTON, Charles (Oldham).
LUND, Arthur (Bradford).

Scottish Section

Annual Meeting

The annual meeting of the above-named Section of the Textile Institute took place on Saturday, 14th March, at the North British Hotel, Edinburgh, when there was a representative gathering of members. Mr. Andrew R. Geary (Dunfermline) was voted to the chair in the unavoidable absence of Mr. J. Macpherson Brown, who, as a representative of the National Association of Scottish Woollen Manufacturers, had proceeded to America on a delegation arranged by the Overseas Trade Council.

The Chairman said he was glad to see so representative a meeting. In addition to the absence of the Chairman of the Section Committee, it was to be regretted that Mr. J. C. Campbell (Galashiels) was prevented from attendance owing to illness. The Section covered a widely scattered area, and bearing this fact in mind, he thought they must all agree that the meetings during the past session had been most successfully organised by Mr. Blair, the Hon. Secretary.

The minutes of the previous annual meeting were approved.

The Hon. Secretary (Mr. A. W. Blair) reported that the membership at end of last session (28th February 1931) totalled 83 (as against 80 for the previous year), distributed as follows—East and Midland, 30; West and South-west, 26; Borders, 24; and North, 3. Mr. David Watson (Paisley) was to be congratulated on having qualified for the A.T.I. There had been three Section Meetings—at

Dunfermline, Paisley, and Galashiels respectively—and thanks were given to all who had assisted in facilities and hospitality in connection with the meetings.

It was decided to increase the Section Committee from four to six. Nominations were invited and it was agreed that the following be elected—Messrs. J. Macpherson Brown, A. R. Geary, T. M. Lees, A. W. Blair (Hon. Secretary), Andrew Smith, and A. J. Hall, with J. P. Beveridge (Member of Council), ex-officio member.

The Secretary presented a financial statement for the year showing the total expenses to have been £10 11s. 8d.

Mr. A. W. Blair was unanimously re-elected Hon. Secretary and heartily thanked for past services.

A discussion followed in regard to the *Journal of the Institute* and its contents. Some members argued in favour of the widening of the field of publication, and others maintained that the existing form was satisfactory. It was urged that the Publications Committee might consider the Abstracts from the point of view of covering all fibres or all branches of the industry.

The Hon. Secretary was instructed to send a cable to Mr. J. Macpherson Brown, wishing him success in connection with his visit to America.

The question of further Section Meetings was discussed and it was agreed to pursue inquiries as to visits to Musselburgh and also Dundee. It was also agreed to recommend members to communicate suggestions to Mr. Blair.

After luncheon, Mr. A. Fairgrieve (Galashiels) opened a discussion on the subject of humidity and temperature in the case of wool spinning. He said that as a result of investigations he had experienced tremendous variation in humidity and temperature under conditions of steam heating. He found that the ideal day occurred in March, with a relative humidity round about 70° and temperature about 65° dry bulb. He turned to the cotton industry for information as to artificial humidification and since adopting a scheme and abandoning steam pipes the conditions did not vary beyond 1 or 2 degrees. The result was more level spinning and practically no trouble in restarting after week-end stoppage. The cost was greater than steam heating, but they were getting the results required, the atmosphere was frequently changed, there was freedom from draughts, and electrification trouble was cured.

Mr. Geary and others took part in the discussion, and Mr. Fairgrieve was warmly thanked for his contribution.

Irish Section

Annual Meeting

The annual meeting of the members of the Irish Section of the Institute was held at the Municipal College of Technology, Belfast, on Friday, 27th March 1931, Professor Bradbury occupying the chair. Dr. Gibson and Mr. W. H. Webb (Randalstown), who had been detained at another meeting, attended later. Apologies for absence were read from Mr. W. H. Webb (Newtownards) and Mr. F. Anderson (Portadown).

The minutes of the previous annual meeting (2/3/30) were read and passed.

The Hon. Secretary (Mr. F. J. W. Shannon), in presenting the annual report, stated that during the past session two meetings had been held at which papers were contributed as follows 6th November 1930, "Properties of Artificial Silk as affecting Industrial Uses," by A. J. Hall, B.Sc., F.I.C., F.T.I.; 22nd January 1931, "Scientific Development in the Linen Trade," by Dr. W. H. Gibson, O.B.E. Both meetings were well attended. The membership of the Section stood at a total of 37, being an increase of three for the year. Regarding the Institute *Journal*, it had been recommended that this should contain some matter of a more general character which would appeal to a large percentage of members.

All members were asked to make a special endeavour to attend the Coming-of-Age Celebrations, at which the Irish Section seemed to have acquired a full share of the honours, as one of our members, Dr. Gibson, had been asked to give a lecture on 24th April, whilst another member, Prof. Bradbury, had been recommended for one of the Institute Special Service Medals. In conclusion, the Committee wished to thank Mr. Hall and Dr. Gibson for papers contributed, and Professor Earls for facilities for the holding of meetings at the College.

On the proposition of Mr. McEvoy, seconded by Mr. Cowden, the report was adopted.

It was decided to send forward five names in addition to the Chairman and Hon. Secretary to constitute the Irish Section Committee, and the following were recommended to Council for re-election—Messrs. W. H. Webb (Randalstown), Chairman; F. J. W. Shannon, Hon. Secretary; and Committee—Dr. Gibson, Professor Bradbury, F. Anderson, W. J. Cowden, and J. Kirkwood.

Subjects suitable for lectures were discussed and it was decided to leave the matter of arrangements in the hands of the Committee, Dr. Gibson and Prof. Bradbury being instructed to discuss the matter with the General Secretary when at headquarters.

Midlands Section

Meeting at the Technical College, Loughborough, on Monday, 2nd February 1931; Dr. A. Bramley in the chair.

YARNS FOR THE HOSIERY TRADE

This lecture was delivered by Mr. S. Kershaw, of the Technical College, Bradford, who said that Yorkshire woollen and worsted spinners would like to supply Midland hosiery and knitted fabric yarn demands. In the early days it had been considered that the requirements of the weaver and of the knitter were identical. Forty years ago supplies were ply-yarns of a thick character, 5/12's to 3/20's being the main range. Though some attributed the growth of the hosiery trade to the post-war requirements of sports and semi-sports wear, said the lecturer, he ventured to say that the real knitting trade of to-day is the making of all classes of underwear, this being due to the overdue reforms in dress, both in styles and in quantity. For warmth and lightness combined, the knitted fabric, said Mr. Kershaw, was superior to the woven. Turning to the yarns involved, the lecturer referred to the different properties of the various fibres as hosiery or clothing yarns, but dealt in detail with wool which he said had peculiar properties to recommend it for use as clothing. Mr. Kershaw then gave a brief outline of the various kinds of wools chiefly used for hosiery yarns, referring to English Down wools, and South American wools, though, he pointed out, there were millions of half-bred sheep with Down sires producing splendid and cheap wools for hosiery yarns. The finest and most popular wool for the hosiery trade, however, was undoubtedly the Merino. The lecturer then described the processing to which hosiery wools were subjected in order to produce the yarns suitable for knitting. He asserted that, contrary to many previous statements, cop-spun yarns were, if not given too much twist, admirable for hosiery purposes. The hosiery trade, being less particular than the weaving industry on the point of yarn strength, and being favourably inclined to the use of yarns spun from short wools, offered the wool man an outlet for many short-stapled wools. Here the lecturer gave a brief description of the processing of such wools for hosiery yarns, dealing with the order of the processes and the desirability of improving such processes as carding, backwashing, etc. The respective merits of Heilmann, Noble, and Square-motion combs were discussed by Mr. Kershaw, as were the three systems of drawing—open, cone, and porcupine—for the production of

hosiery yarns from short wools. Turning to the spinning frame, the lecturer said that here the hosiery yarn was made or marred. The cap tube revolutions should be reduced to about 5,000 r.p.m., but, in regard to yarns generally, the process employed depended upon the ultimate use of which the yarns were to be put. The ideal might be fly-spun yarn at cap-spun prices, but this was hardly possible said Mr. Kershaw. Ring-spun yarns were an intermediate proposition, being better than cap yarns and somewhat inferior to fly yarns. After-processes including twisting, folding, fancy twisting, and winding were next dealt with and suggestions made as to the larger employment of fancy or novelty yarns in the knitting industry. Finally, the lecturer dealt with the production of coloured yarns which, he said, chiefly emanated from Huddersfield. He concluded by saying that all textile processes and knowledge were undergoing a searching reinvestigation and interest keen in developments, which gave promise of cheaper production, increased output, and improved quality.

A hearty vote of thanks to the lecturer concluded the meeting.

London Section

Meeting at the Barratt Street Trade School, London, W., on Tuesday, 13th January 1931; Mr. S. A. Williams in the chair.

THE PROPERTIES OF THE VARIOUS TYPES OF RAYON

The above was the title of a lecture delivered to members of the London Section of the Institute by Mr. A. B. Shearer, of Messrs. Courtaulds. He said that it was first necessary to get a clear idea as to what were the properties essential to textile raw materials. The first property to consider was that of strength, though what was necessary for one type of fabric was not necessary for all types. On similar lines, the lecturer discussed pliability, colour, lustre, wearing power, and dyeing properties. He then turned attention to the following types of rayons—Chardonnet, cuprammonium, viscose, and acetate rayons—suggesting that their relative values commercially were indicated by the bulk production of each type. Up to about 1910, nitro-cellulose was in the lead, being about 48% of the total rayon production; to-day, viscose constitutes about 87% of the total production, and nitro-cellulose rayon has fallen to the last place. The lecturer then discussed the reasons why nitro-cellulose and cuprammonium rayons had fallen out of the world's markets, and pointed out that, despite the persistence of fine-filament fine-denier yarns of cuprammonium type, neither possessed such outstanding textile qualities as to offset their higher costs of production. Indeed, the lecturer asserted, it was probable that any continuance of demand for fine-filament yarns would result in such yarns being produced by viscose makers. Turning next to acetate rayon, Mr. Shearer described its peculiar properties, such as its dyeing affinities which differed from those of the other rayons, and its handle which was warmer, and its draping qualities. He then enumerated the wet and dry strengths in terms of grammes per denier of the different rayons, and pointed out that extra strength was not necessarily an advantage, as in weaving an extra strong rayon thread would cut a cotton or linen warp. The object of increasing strength was to secure finer filaments and greater resistance to processes which involved wetting. Other qualities of rayon, such as their bleaching and dyeing properties; the possibility of securing more intense colours, such as reds, on rayon; the weaving power of viscose yarns; and its pleasing qualities as underclothing were dealt with by the lecturer. An interesting discussion followed, during which Mr. Shearer answered a number of questions. A hearty vote of thanks ended the meeting.

REVIEWS

Textiles for Salesmen. By E. O. Ostick. Published by Sir Isaac Pitman & Sons, London. (164 pp. and Index, 5s. nett.)

This book makes a bold attempt to supply the non-technical salesman with information likely to be of use in helping him to understand something of the construction and composition of the different fabrics he has to sell. The author states in his preface that the book is merely an introduction to a very wide subject and necessarily omits much of importance. This is certainly a fact, but it could scarcely be otherwise in a small volume at such a modest price. The book deals with the subject from fibre to fabric and includes those of animal, vegetable, and artificial silk origin. If, as the author suggests in his preface, a demand for such a book exists, it could have been better met by a series of books of a similar nature but each dealing with one branch of the trade, such as woollens and worsteds, cottons and linens, silks and artificial silks, etc., and thereby giving more detail and a fuller explanation of the processes described. Chapter 2, dealing with the examination of fibres by the microscope, particularly illustrates this conciseness and the student would certainly have to consult other books if he is to identify the various fibres used in the textile trade. Moreover, some of the illustrations in this chapter are rather crude, and photo-micrographs instead of sketches would greatly improve this section. Again, chapter 11 on the estimation of yarn counts from a piece of woven cloth; a piece of cotton cloth 2 in. × 2 in. is taken and the calculations based on the assumption that the yarns extracted will be exactly 2 in. in length. This in itself will lead to an erroneous result, quite apart from the fact that the warp in particular may contain a large amount of sizing materials. On the other hand, other parts of the book are well done. Chapter 3, for example, shows clearly the fundamental principles of the intersection of warp and weft in the simple weaves and is very well illustrated. The latter part of the book dealing with dyeing, printing, and finishing is, though concise, well done and should give the salesman some idea of how colour is applied and the various finishes are obtained. On the whole, the book is good, well written and interesting to read, and should be of great use to the non-technical salesman. It should certainly act as an incentive to students to consult other books which deal more fully with the various branches of the subject, as is suggested by the author.

G.A.R.

Die Indische Baumwollindustrie. By Dr. rer. pol. Helmut Pilz. Published by Julius Springer, Berlin. (185 pages, 12 R.M.)

The author describes the hand cotton loom industry during the time when the East India Company were in being, from 1608 to 1859, and the industry's decline, due to the competition from Lancashire. He infers that this decline was also attributable to the Acts passed in England in 1721 and 1774, which prohibited the use and wearing of Indian-made cotton goods, but it should be pointed out that cotton goods were allowed entrance to England provided they were destined for export. A further description is given of the founding of the present cotton industry in India. The author also deals very fully with the question of labour in the Indian cotton mills, describes the living conditions, and welfare work undertaken by the millowners. Some interesting tables are given showing the districts from where the operatives are recruited. Another chapter deals with the quality of the Indian cotton used and the endeavours which are being made to improve the supply. Reference is also made to the different aspects, from an Indian point of view, of the question of customs duties on cotton cloths entering into India.

N.S.P.

Industrial Britain. By Albert Wilmore, D.Sc.(Lond.). Harrap's New Geographical Series (348 pages, Bibliography, and Index, 5s. nett.)

Dr. Wilmore has produced an exceptionally fine and readable summary of the whole field of British industry. How large that field is it is difficult to realise until one begins to think seriously about it. Then the mind is impressed with its magnitude and its vital importance to millions of human beings. The localisation of one industry in one part of the country and a different industry in another area is as carefully and fully treated as space permits and the regional differentiation

so puzzling to many people has a new light shed upon it. Wherever historical factors are mentioned in connection with the localisation of the cotton industry in Lancashire no reference is ever made to the influence of the slave trade of Liverpool, and yet this would seem to have been of great importance, for raw cotton formed a return cargo from the American plantations to a port which became even more important than Bristol in this kind of trade. The metallurgical industries are well treated and the explanation of the change over in the relative importance of the black band ironstone as compared with the Jurassic should prove of interest. The whole work is one which should be read by every teacher and every senior student of geography. It should prove of great interest to the general reader and especially to the industrialist by helping him to obtain a wide geographical outlook, so necessary in this modern world where the development of transport has made all countries and races such near neighbours one of another. H.W.O.

Cotton Year Book 1931. Published by the Textile Mercury Ltd., Manchester. (Pp. 712 + cxxiii. Price, 7s. 6d.)

In spite of the heavy depression in Lancashire's main industry, the twenty-sixth edition of this Year Book again furnishes informative and interesting matter. All sections have been revised and brought up-to-date. Section I—Review of the Cotton Trade 1930—contains some pertinent statements on the Bombay situation and the general effect on trade of our present relationships with India. It is to be hoped that when the 1931 Trade Review is written it will be possible to indicate a much brighter outlook. The last section of the book—Trade Associations, etc.—in its revised state is, as always, extremely useful in that it is a special feature of this series of year books. T.

Wool Year Book 1931. Published by the Textile Mercury Ltd., Manchester. (Pp. 712 + lxxv. Price, 7s. 6d.)

The twenty-third edition of the Wool Year Book, like its companion volume the Cotton Year Book, prefaces its chapters by deploring trade conditions in the woollen and allied industries. New chapters have been added to this edition which show that though trade may not have warranted changes and new developments, yet a good deal of progress has been made. A chapter indicates the changes that have taken place in regard to the supplies and quality of raw material in the various wool-producing countries and the advantages derived from research work in this connection are recorded. A short history of the artificial silk industry, together with statistical information is again a feature of the book. T.

The Marketing of Wool. By A. F. du Plessis. Published by Sir Isaac Pitman and Sons, London (331 pp. and index, 12s. 6d. nett).

The author claims that this book is "the first serious attempt at examining the mechanism of the distributing process," and this claim may be accurate so far as literature in book form is concerned. That research into the Marketing of Wool—distribution research it may be termed—is as necessary as research in the production and in the manufacturing spheres of the wool industries, may be at once acceded though it may be well to state that these aspects of research are not quite so neglected as the author seems to think. But the book itself has the merit of focussing attention on the structure of the marketing of wool as a whole, and its imperfections may readily be excused on that account. The first four chapters—The Production of Wool; The Manufacturing of Wool; The Preparation of Wool for the Market; and the Standardisation of Wool—occupy more than their fair share of space, and lead the author into those realms of research which he suggests have been neglected and with which he would appear to have neglected to make himself thoroughly familiar. But notwithstanding these criticisms, the remaining chapters, which deal with Private Treaty Sale of Wool; Local and Central Public Wool Auctions; Co-operative Marketing of Wool and Control therein; with Statistics and Marked Information; and with Credits and Prices, certainly present a picture of wool distribution not otherwise available so far as the reviewer knows, and which is therefore worth while as a basis for further investigation, albeit amendment of the base may prove necessary *ab initio*. T.

Textile Recorder Year Book 1931. Edited by John Brooks. Published by John Heywood, Ltd., Manchester (pp. lxxiv+898. Price, 7s. 6d.)

In addition to revising all the former sections of the Year Book, a new section on the dyeing of rayon has been added. This deals with the latest methods of dyeing rayon yarns and all-rayon fabrics, methods adopted for the dyeing of various types of rayon, and the dying of mixed fabrics containing rayon. The inclusion of this information increases the value of the rayon section. The new illustrations in the section devoted to the microscopy of textile fibres are a great improvement on those formerly shown, but a minor criticism occurs in this connection. In the Preface attention is drawn to the new illustrations by stating that they will take the place of those which "formerly appeared on pages 3 and 4," but it does not add the information as to where thay appear in the 1931 edition. Actually they are to be found on pages 699-702, but this takes a little finding and a search of the contents list. It might also be suggested that the Contents List and General Index should follow the title page, as they form the key to the mass of information contained in a year book, and are of special importance when the edition runs to nearly 900 pages. T.

Popular Research Narratives. Published by Balliere, Tindall & Cox, London. (viii+174 pages and 5 plates. 4s. 6d. nett.)

Though the volume under notice is No. III of the series, it is typical of the other two. In an introduction Brig.-Gen. J. J. Carty, of the U.S. Army Reserves, says—"The publication of these Research Narratives does more than provide scientific reading in an entertaining and instructive manner. They constitute in themselves a distinct contribution to the cause of scientific research because they present to the reader authentic form, concrete examples of the methods, vicissitudes, and triumphs of scientific research." After reading the "narratives" in Volume III, this pronouncement may be endorsed. Each chapter, a complete story in itself, is contributed, if not by the actual research worker whose work is described, by an authority intimately connected and familiar with the specific researches. There are few, if any, of these "narratives" of direct textile interest, but each has a definite appeal to those who are wise enough to study scientific method as a preliminary to engaging in or as an avenue to the appreciation of technical and scientific research. T.

THE JOURNAL OF THE TEXTILE INSTITUTE

Vol. XXII MAY 1931 No. 5

PROCEEDINGS

COMING-OF-AGE CELEBRATIONS

Manchester, 22nd, 23rd, and 24th of April 1931

THE INSTITUTE AND THE FUTURE

Youth, having attained its majority, naturally anticipates those enjoyments associated with being "grown-up." That they are accompanied by harder work, sterner responsibilities, and keener disappointments remains to be discovered and the manner in which adult life is faced is a measure of the quality of youth. Without pressing the analogy too far, it may be claimed that the Textile Institute having attained to a like age must face similar problems. It is fortunate, however, that, though young as an organisation, its direction is in the hands of experienced men and the wisdom acquired in other spheres of activity can be applied to Institute problems. It may be well, therefore, on the threshold of a new era, to look for landmarks in the "promised land" and to study a little more carefully the "sailing orders" already in our possession. The first of these is undoubtedly the "Scheme of Development" drawn up and approved by Council in 1919 and the second is the "Royal Charter" granted in 1925. To these two documents we must look in the future for guidance in the adult life of the Institute. The "Scheme of Development" suggests activities which may be placed in two groups—the first group being general Institute functions and the second Sectional functions. In group one it may be claimed that real progress has been made—the Diplomas Scheme, the Institute's *Journal*, the Mather Lecture, the Institute and Warner Medals, the Library, and the Bureau of Inquiry are established and steady persistence in each case can only result in sound growth. These are matters that are in the hands of Standing Committees and every confidence may be felt in their proper functioning. In group two, which covers Sectional activity, more uncertainty exists perhaps. It is not abnormal to find that in a growing organisation its branch activities are less defined than those of headquarters, but there can be no doubt that the question of Section development is of the most vital importance to the Institute.

The second document to which reference has been made is the Royal Charter, granted in March 1925, a document that repays constant study in discussing Institute policy and plans. That Charter constituted the Textile Institute for certain specified objects, first and foremost of which was "to advance the general interests of the Textile Industry more particularly in relation to the acquisition and application thereto of scientific knowledge." Here in a sentence is the main policy of the Institute defined; all activities should be designed to promote this object whether directly or indirectly. That some indication of the outlook as envisaged by those holding office in the 22nd year of Institute existence may be available the following communications are published. They indicate clearly that the magnitude of the task is not unrealised and that there is abundant confidence in the ability of the Institute to tackle that task adequately.

From Mr. Geo. Garnett—President-Elect.

The Coming-of-Age of the Institute celebrated in April brought to mind the programme of development which was in the minds of the founders, and an examination of the progress that the Institute has made during these years in its endeavour to fulfil these ambitions, and to become recognised as one of the official mouthpieces of our textile industries. A review of its activities, both scientific, technological, and literary, as well as its recognised status, proves beyond all doubt, not only the great need for such an Institution, but the justification for its continued support.

It must continue to gather to its aid and to enhance its influence the best minds in all associated subjects and it must become the platform for the pronouncement of advanced thought, and activity, on any subject germane to the development of the textile and allied industries.

I would like to see greater emphasis laid upon the more definite association of art with industry. Owing to the difference in the standard of living between Western and Eastern peoples and corresponding rates of remuneration, it is probable that competition for plain fabrics will in the future become much keener as the Far Eastern nations develop technically. We must, therefore, produce fabrics of greater attractiveness not only in design, but in colour, so that we may secure such a share of international trade as will maintain in employment a high proportion of our own industrials.

The phenomenal depression which is affecting the world at the present time has many causes and many effects. The upheaval caused by the war is still evident in realms of finance, economics, costs of production, transport rates, and national expenditure. Radical improvement in all these realms is vital to recovery, and no matter what our Universities, Colleges, and Institutes may do, these major problems are at the moment at the very foundation of our future progress. In this direction the Institute leaves the study of such subjects to institutions specially equipped for dealing with them, and specialises in the educative and equipment side of industry from a scientific and technical point of view. This condition of affairs will not always last and we must prepare for that natural demand for wearing materials that will come about by the restoration of confidence, where beauty of decoration and colour at a reasonable price will command first attention.

We fully recognise that much valuable work has already been done through such Institutes as the British Institute of Industrial Art, but it is in this direction, I think, we must look for greater achievement, and our Institute can play a very important part in seeing that the right emphasis is given. With a more complete union between industry, science, and art, I believe we shall maintain our lead in all those larger aspects of textile industrial success which have brought us, up to the present time, to our position of domination. (Signed) GEO. GARNETT

From Mr. F. W. Barwick, Chairman, Selection Committee (Institute Diplomas)

In its initial efforts to bring into operation the scheme of awarding professional qualifications to members of the Institute, under the powers granted by the Royal Charter of 1925, the Selection Committee fully realised the magnitude of the responsibility which it had undertaken. In the light of subsequent experience, it is now a matter of satisfaction that the Committee did not proceed at once with the actual framing of definite regulations. In the early stages, it was appreciated that new ground was to be broken. The Committee accordingly proceeded to administer the scheme on the basis of acquiring actual experience in dealing with applications, and it was not until September 1927 that printed regulations were issued. Although the claim may now be fairly made that the conditions imposed in relation to applications for the Fellowship and Associateship have proved effective in practice, nevertheless, the possibility of improvement by modification has not been overlooked. Actually, at the present time,

a special Sub-committee of the main Selection Committee is about to give consideration to certain clauses of the provisions, more particularly those governing the requirements in connection with applications for Associateships.

In order to function efficiently, the Selection Committee has of necessity to be representative of many interests—and in this connection it may be observed that it numbers on its panel members possessing wide scientific, technical, educational, and industrial experience. It is of interest to record the stages through which an application for Associateship or Fellowship passes before a recommendation is forwarded to the Council of the Institute. Details of the application are first circulated to all members of the Selection Committee. The case is then considered and discussed at a meeting of the Committee, and a provisional decision is arrived at. Such decision is communicated to all members of the Committee prior to the following meeting, when the case is again discussed. If the original decision is confirmed, a recommendation is accordingly forwarded to the Council for its final approval. Whilst this procedure may appear unnecessarily protracted, it affords a candidate the greatest measure of consideration and at the same time secures most desirable protection of the interests of the Institute.

Admittance to the Institute's Examination in General Textile Technology, usually held twice each year, in June and December, is permitted only to applicants for the Associateship whose attainments up to that stage have been approved as conforming to the requirements of the Charter and Bye-laws and are therefore eligible for examination. In itself the examination constitutes no qualification, but is the means adopted by the Institute to ensure that those holding its diplomas are "technologists" possessing not only a highly specialised knowledge of their own branch of the industry, but also an outlook widened by a general knowledge of other branches. Having regard to this restriction of candidature, the attendances for examination have been highly satisfactory in number. The next examination, on the 17th June, appears likely to provide a record as to number of candidates who will attend, and arrangements have been effected for simultaneous conduct of the examination at Manchester, London, Belfast, and Glasgow. This is evidence of the growing appreciation of the value of the scheme and there are grounds for believing that the industry generally is realising the value of the Institute Diplomas. (Signed) F. W. BARWICK

By Mr. W. T. Boothman, Chairman, Lancashire Section Committee

In relation to regional activities, the Institute has now six Sections—Lancashire, Yorkshire, London, Ireland, Scotland, and the Midlands. In each instance the affairs of the Section are controlled by a Committee elected by the members located in the respective Section areas. The activities of a Section are primarily associated with the organisation of meetings for the reading and discussion of papers. Whilst Headquarters has always been both willing and anxious to assist Sections in every possible way, yet it would appear that the ideal Section is that which, by means of its Committee, fully meets its obligations in regard to the preparation of an annual programme of meetings. This involves the selection of subjects to be dealt with and the securing of the services of contributors of papers or the arrangement, it may be, of visits to works or even, perhaps, the holding of an annual social event. As contributions to textile literature now form a definite consideration in regard to award of Diplomas of the Institute, it has been rightly urged that Section meetings should afford occasional opportunity for members, particularly those in the Section area, to present papers with a view to subsequent publication in the *Journal* of the Institute. Such papers should preferably be original in character containing records of observations and experiments. The suggestion has been made that Section Committees should select and urge particular members to make contributions on subjects known to be within the compass of their abilities, and special endeavour might

occasionally be made to secure the services of some of the younger members, who have already attained Associateship rank. In my experience in relation to the activities of the Lancashire Section, I have found that the interest of a meeting need not necessarily be limited to the paper contributed. These meetings provide an opportunity for friendly discussion of matters of mutual interest, and this form of intercourse has often proved highly beneficial. In the case of Lancashire, the arrangement under which meetings are promoted in various towns in the area has consistently proved advantageous, and co-operation on the part of local textile organisations has usually been secured without difficulty. Though success in the organisation of Section meetings depends largely on the suitability of the subject of the paper to be contributed, yet members of the Section Committee are expected to use their influence locally as far as ever possible. In regard to what may be described as district meetings, Section Committees may always rely upon the goodwill of the local Education Authorities concerned, so far as facilities for meetings and lecture-hall accommodation are concerned. The prospects for the future in relation to Section activities are probably greater to-day than they have ever been from the point of view of the promotion of successful meetings for the reason that interest in the scientific and technical side of the industry has widened enormously in late years. Great opportunities exist to-day for this Section activity, and it is hoped that Section Committees of the Institute will pursue their work with unflagging enthusiasm. (Signed) W. T. BOOTHMAN

From Mr. W. Kershaw, Vice-Chairman, Publications Committee

Looking forward to the work of the Publications Committee, now that it, along with the whole Institute, has come-of-age, is of special interest, but it is perhaps unwise to prophesy. I will confine myself, therefore, to such indications of progress that are reasonably definite and from which members may expect concrete advances. Mr. J. H. Lester, himself for some years Chairman of the Publications Committee, was kind enough to say at the Coming-of-age Banquet that in his view the conduct and development of the *Journal* was of prime importance to the Institute. Those concerned with its production, therefore, are entrusted with a heavy responsibility, and, I think it may be said, fully realise it. Following some criticism of a practical character a special sub-committee of the Publications Committee has been appointed to investigate and report upon every aspect of *Journal* work. It would be discourteous as well as impolitic to anticipate that report but it is quite in order, I believe, to state that certain general principles are firmly fixed upon which *Journal* production can be based. In the first place, the *Journal* must constitute a record of Institute development generally. It is also the medium, now world-widely known, for the publication of original work in textile technological research. In this direction the connection between the work of the Selection (Diplomas) Committee and that of the Publications Committee is very close. In the communications which precede this it will be found stated clearly that "publication of contributions to textile technology through the *Journal*" constitutes a definite consideration for progress from the Associateship to the Fellowship of the Institute. No barrier, save that of merit, will be placed across this avenue of development. Its abstracts, which are sought by subscribers in over 30 countries, are at the moment the subject of close examination, but whatever policy may ultimately govern their contents and production, there can be no question but that they will continue to form a very important part of the *Journal*. On more general lines, there is a demand for advance and it will be the Committee's wish, I feel sure, to meet members' requirements as fully as possible. Financial restrictions, of course, exist and perhaps always will, but so far as possible publication will be made to the full. Section Committees, whose work is described above, have a deep responsibility in this direction. No one can possibly know local conditions or get into touch with local talent with such readiness and accuracy as can the Section Committee, and

the Institute looks to these bodies to help in the securing of contributions of a general character. Of publications outside the *Journal* a word may be said—The Chronological Record, issued at the time of the coming-of-age celebrations, represents a step forward in publication policy and should prove of value to all members. The Committee confidently expects a generous demand from members for copies of this volume. There has been a steady demand for the Report of the Empire Textile Conference held at Wembley in 1924, and for the special issue commemorating the Crompton Centenary celebrations at Bolton in 1927. In favourable circumstances a more ambitious programme of publication will be undertaken and all members are invited to give the Institute's work in this connection serious consideration. Help is possible in several directions, and will be welcomed for the general good of the Institute. (Signed) W. KERSHAW

THE CELEBRATION OF TWENTY-ONE YEARS' ACHIEVEMENT

Though purely an arbitrary period, 21 years in the life of an individual has come by law and custom to have a definite significance. To have lived thus long is to have attained one's majority, and henceforward manhood or womanhood is attributed to the twenty-one year old even if the quality be more apparent than real. In 1910 the Textile Institute was founded; it was natural, therefore, to consider the celebration of the Institute's majority this year, and the Council some months ago decided not only to make these celebrations distinctive in character, but to use every effort to secure from them the fullest possible propaganda value.

The celebrations commenced with a reception at the Midland Hotel, Manchester, on Wednesday, 22nd April, by the President, Lieut.-Col. B. Palin Dobson, and Mrs. Dobson, and the Chairman of the Council, Mr. Frank Nasmith, and Mrs. Nasmith, on behalf of the Council of the Institute. It was at this gathering that the opportunity was taken of presenting to Mr. J. W. Nasmith, inventor of the Nasmith Comber, the certificate of Honorary Fellowship of the Institute, which was handed over to the recipient by the President.

THE HONORARY FELLOWSHIP OF THE INSTITUTE

The Royal Charter granted to the Textile Institute in 1925 *inter alia* gave the Institute the power to elect Honorary Fellows, and it was decided thereupon that such distinction should be reserved as the highest honour the Institute could accord. The breadth of outlook shown at this time is further indicated by the fact that it was also decided that only an achievement of real magnitude and of definite and generally-recognised benefit to the textile industries should entitle an individual to consideration for this award. A measure of the value placed by the Council of the Institute upon its Honorary Fellowship is to be found in the history of the awards made to date. Only two, prior to that now to be made have to be recorded. In October 1928, on the occasion of the Institute's Autumn Conference in Bury, *Charles Frederick Cross*, with whose name are associated those researches and inventions that inaugurated not only the manufacture of viscose filaments, but indicated the manifold uses to which that supposedly inert substance, cellulose, could be and has subsequently been put, and *Horace Arthur Lowe*, whose recent death is much to be deplored, and with whom the invention whereby tension was applied to cotton yarn while it was undergoing the action of caustic soda, is associated, were made the first Honorary Fellows of the Institute. On the twenty-first birthday of the Institute, a third Honorary Fellow was added to this small and select body of men.

John William Nasmith, who was a pupil at Chorlton High School, in its day a rival of the Grammar School, was subsequently an evening class student in engineering at Owens College under Professor Reynolds. His further acquaintance with engineering was made as an apprentice with John Hetherington & Sons,

of Ancoats, for which firm, in 1879, he proceeded to Italy as an erector. Returning to England with a first-hand knowledge of French, Mr. Nasmith worked as assistant to M. Lecoeur, the inventor of the Hetherington Pinel Lecoeur Comber—a machine which, though ingenious, was before its time. Many of these machines were erected on the Continent and as recently as 1914 were still at work. In 1886 Mr. Nasmith again returned to the Continent as representative of his firm, this time to Dresden and later to Mulhouse. Later he became a Director of Messrs. Hetherington, but resigned to join Messrs. Howard & Bullough Ltd., for whom he visited the United States and Egypt. In 1901, the comber with which his name is associated, and which constitutes his claim to be numbered among those to be honoured by the Honorary Fellowship of the Institute, was completed, and Messrs. John Hetherington & Sons granted the sole license to manufacture it. The machine was not originally intended as a competitor to the Heilmann Comb, but rather to comb cottons for which the Heilmann was unsuited. It was found by its users that it could be applied with advantage to the combing of the finest cottons, and its use soon became universal. Though the master patents of his comber were taken out in 1901, Mr. Nasmith's work leading up to them was initiated several years before and many trials had to be made before the final measure of success was secured. That that success was outstanding is to be realised not only from the fact that the patents stood unchallenged until they finally expired, not only from the fact that copies of the comber were subsequently marketed as "Nasmith Type" combers, but also from the fact that numerous mills and combines installed combers which hitherto had only used cards. Mr. Nasmith's inventive genius did not stop at this point, but he turned his attention to steam traps, damper regulators, and later to cardboard box making machinery, which up to that time had been chiefly imported from Germany. The box-making venture prospered to such an extent that in 1918 negotiations were completed for Messrs. Vickers Ltd. to take it over. In 1924, a new model of his comber was introduced, and at present Mr. Nasmith is devoting attention to the combing of short wools.

Mr. Nasmith was introduced by Mr. W. Scott-Taggart, M.I.Mech.E., F.T.I., who remarked that when he was first informed that he was the person selected to perform that duty, he thought it was a splendid opportunity of launching a tirade against the present system of organisation and management of the textile industry. While he remembered, however, that this was a birthday party, and that they ought to be bright and cheerful, he could not let the occasion pass without some slight reference to the great textile industries of these islands. Without doubt, the textile industry was the greatest in Great Britain; taking one section of it alone—cotton—with the exception of agriculture, must be the greatest industry in Great Britain. Its greatness was not merely confined to the operation of buying and selling cotton yarn, and to textile mills set up all over the country; many large engineering works were part and parcel of the textile industry, as were the multitude of subsidiary firms which depended on the textile industry for their existence. Some idea of the extent of the cotton industry might be secured from the knowledge that within five miles' radius of Bolton Town Hall there were more spinning spindles than in the whole of Germany, and within a similar radius of Oldham Town Hall there were more spindles than in the whole of France and Germany together. This industry had produced its mechanical geniuses who, honoured and revered, had their niches in the halls of fame. One of those geniuses was now standing before those present, and he thought he could safely say that if not the greatest inventor of all time, John W. Nasmith was certainly the greatest since the Textile Institute was formed. His duty was to introduce to the President a man who invented a machine called a comber. Prior to its introduction there was already a cotton comber in existence, and he might incidentally mention that a statue was erected to the memory of Heilmann, the man who invented it. Whether a statue would

be erected to Mr. Nasmith he could not say, but the Textile Institute were recognising the great value his invention was to the textile industry. His machine had been brought to perfection after years of patient effort. Not only had the years of planning and trial to be patiently endured, but also those which inevitably follow the introduction of a new invention, during which the invention awaits the verdict of practical tests. But all this was now passed and the Nasmith Comber had been widely adopted. He stood before them now a proud man, having done something that would live and for which the textile industry would be his debtors for ever. "Mr. President," concluded Mr. Taggart, "may I present Mr. John W. Nasmith to you, to receive at your hands the greatest honour that it is possible for the Textile Institute to bestow on one of its members. He is a worthy man, and he is continuing in the work which has already made him famous, and may this diploma of the Honorary Fellowship of the Textile Institute be an inspiration to him to continue in the work he has already done, and may he live long to enjoy it."

The President (Lieut.-Col. P. Palin Dobson) then handed the certificate to Mr. Nasmith, expressing the pleasure it gave him to do so.

Mr. Nasmith said it was with profound feelings of gratitude and appreciation that he received the honour of the Honorary Fellowship of the Textile Institute, an Institute which was known throughout the world, and which would, he hoped, continue in its good work for many years to come. He was like many other inventors; he could not claim that he was animated in his early days with any idea of benefiting his fellow-man, but rather was moved by ambition to distinguish himself in his profession and to gather in, perhaps, a little of the financial reward that gave those feelings a true background. There was some æsthetic pleasure to the inventor to see his idea materialised and in operation, performing just exactly what he intended it should do. They had heard in the last few months a great deal about the redundancy of machinery in the textile industry, and talk about scrapping a great deal of it. It was obvious to everybody to-day that there was redundancy as far as present-day demand was concerned. Personally, he was inclined to think it was only temporary.

The remainder of the evening was spent in dancing and entertainment was provided by Mr. J. Whitham, vocalist, and Mr. A. H. Stott, conjurer.

PROCEEDINGS ON THURSDAY, 23rd APRIL

The Mather Lecture was delivered on Thursday morning at the Midland Hotel, where all the events, with the exception of the visits and the Public Lecture, took place, the subject being "Current Changes in the Technology of Cotton Spinning and Cultivation," by Dr. W. Lawrence Balls, F.R.S. In the absence of Dr. Balls, the paper was read by Mr. H. A. Hancock, of the Shirley Institute. Mr. H. P. Greg occupied the chair.

The Chairman said he did not think it was for him to attempt to introduce Dr. Balls to the audience. He was in Egypt and they had to be content with his paper and a very admirable substitute as far as reading it was concerned in Mr. Hancock. They all knew Dr. Balls, if not personally, by reputation or by his work. He was still a young man, under 50, and he had done remarkable work. As Fellow of his college at Cambridge he had won early recognition. He was a Fellow of the Royal Society and had taken a very prominent part in connection with research in the cotton trade. He started work in Egypt as a botanist and had made valuable discoveries. He was in Egypt ten years, and then came to England as head of the Research Department of the Fine Cotton Spinners' and Doublers' Association, getting into practical touch with cotton spinning and doubling machines. Later, he again went to Egypt and was still there. We in this country were extremely obliged to Dr. Balls for two things. One was that he had brought very vividly before them the importance of small things. At the beginning of the century they thought of cotton in the

bale and had no clear ideas of anything but the bale. Now they were thinking of cotton in the hair, and the difference between the outlook of the cotton hair and of the cotton bale was extraordinary. There were about 400 cotton hairs to the grain and about 7,000 grains to the pound, so that they could imagine what the difference in the outlook was that was necessary in envisaging the difference between the cotton hair and the cotton bale. The other point Dr. Balls had brought before them, and which was to his mind a point of extreme importance and value, was the drafting wave. He did not know whether Dr. Balls discovered it, but he brought it into prominence, and he, the Chairman, believed that the study of the drafting wave would prove to be a most important thing in the rehabilitation of the cotton trade. He thought the Mission to the Far East had done excellent and good work, but he ventured to say that the cotton trade of Lancashire was going to gain more permanent good from studies in connection with the drafting wave even than from the study of the Report of the China Mission. The study of single hair properties and of the drafting wave were the two points in which he thought Dr. Balls had done wonderful work for Lancashire. He also wished to pay his tribute for the work Dr. Balls did in connection with the inauguration of the work of the Cotton Research Association. Dr. Balls, Mr. J. H. Lester, and Mr. A. Abbott, laid the foundation for cotton research at the Shirley Institute in an extraordinarily able chart, and he thought that Lancashire could never be sufficiently thankful to these three men for preparing for it such a valuable basis for cotton research. Finally, he wished to pay tribute to the personality of Dr. Balls. He came across him, years ago, very frequently; he was a most original man and possessed a most charming personality. He never came across a man whose mind had so few limitations; what his father, grandfather, or great-grandfather did really had no weight with him at all. His mind seemed absolutely free to take up anything he thought advantageous or progressive. He only wished to add that in asking Dr. Balls to deliver this lecture the Institute Council had asked one who was well worthy of a place in the list of Mather lecturers. While they were extremely sorry that Dr. Balls was not present to deliver his lecture, they were glad indeed that the duty devolved on Mr. Hancock, because Mr. Hancock was for ten years in close personal touch with Dr. Balls, and must have imbibed some of Dr. Balls' temperament. He was quite sure they could not have got a better man to read the lecture than Mr. Hancock.

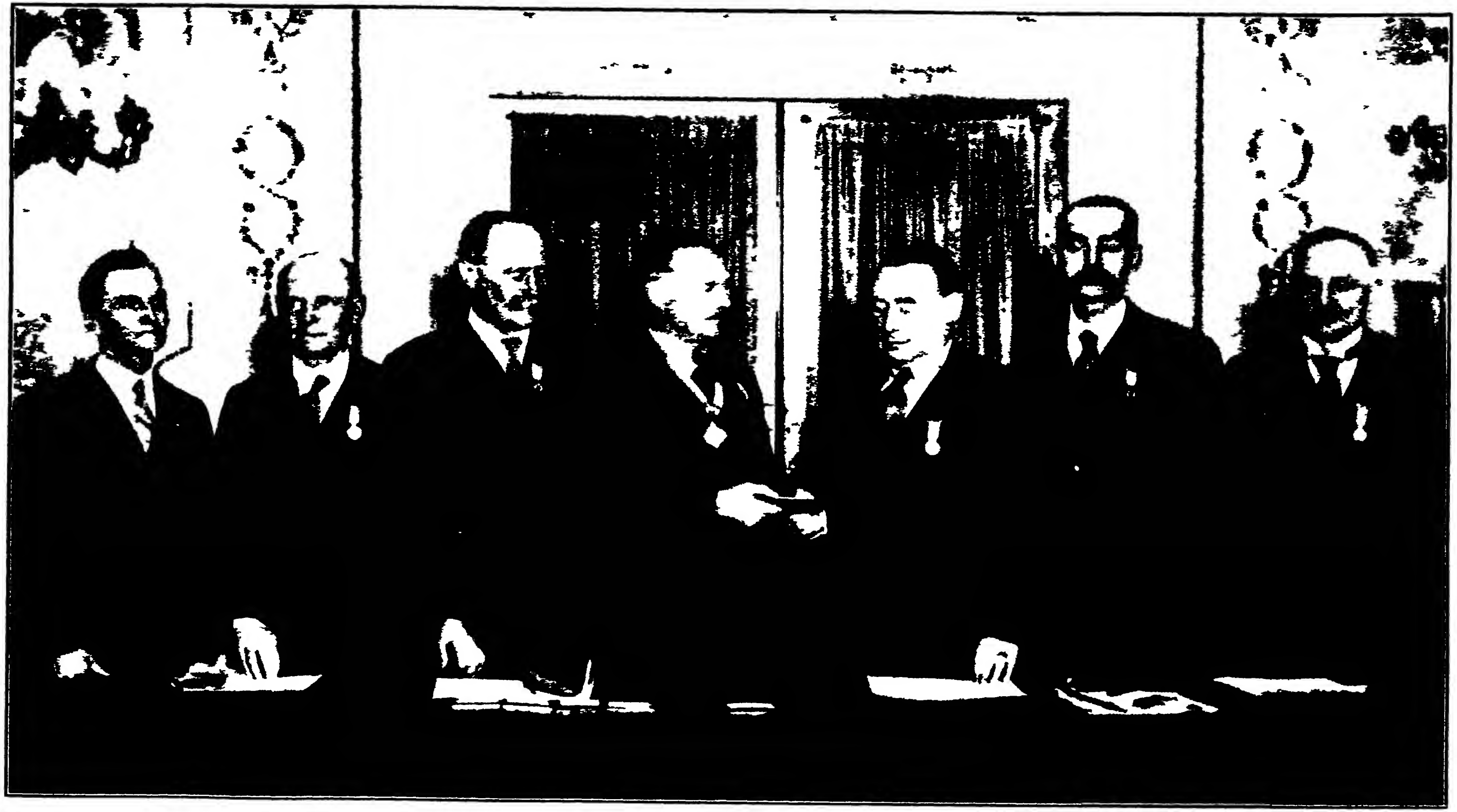
CURRENT CHANGES IN THE TECHNOLOGY OF COTTON SPINNING AND CULTIVATION

W. Lawrence Balls, Sc.D.(Cantab.), F.R.S.

The essential characteristic of a lecture is the personal influence of the spoken word, and when circumstances compel the lecture to be delivered by proxy, as in the present instance, it necessarily loses that essential. But the Mather Lecture of the Textile Institute is read by many more people than those who hear it delivered, so that the incongruity of writing among the cotton fields of Egypt in an attempt to catch the atmosphere of an audience in Manchester, is perhaps more apparent to the writer than to his hearers.

In choosing a subject for such a lecture as this, one would prefer to keep to the safe ground of scientific studies, and expound the development of research work on some particular problem; but although such treatment is of more permanent value, it would make less appeal to an audience drawn from all parts of the textile industry than the broader and more speculative one, which I have selected with much misgiving.

My object to-day is to give an outline indication of some changes which have already taken place in the cotton world during the present century, and to risk some guesswork concerning the future trend of those changes in the remainder



H. Nisbet F. Bradbury H. P. Gee The President J. N. Smith A. E. Barker W. I. Boothman

The Institute Medallists

Coming-of-Age Celebrations

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First recipients of the "Warner" Medal

of the century. Such changes are partly due to world-wide economic causes, but—in so far as the industry shows signs of surviving the impact of those causes—they are largely due to the application of modern scientific methods. These methods have succeeded in making discoveries of things within the industry which the industry itself unaided had failed to find during a hundred years of experience. They have also been utilised in order to apply to the industry the results of discoveries made in the realm of pure science, and—partly on account of the necessary inertia of invested capital in an immense existing industry—this application has scarcely begun even now.

These two components, economic pressure on the one hand, and scientific method on the other, interact to a greater extent than is commonly realised. A stable industry, in a state of equilibrium with its markets and its competitors, is adequately served by its practical knowledge of everyday working practice; an Oldham mill spinning American cotton for the Indian dhooties at the end of last century was typically stable; the pre-war cultivation of Egyptian cotton is another instance. But when conditions change, trouble begins. The purely practical man can only experiment in mass, and most experiments are necessarily failures, so that the cost of experiments on the so-called practical scale is ruinous. The speedy and inexpensive technique of the scientific research worker can follow up such changes of conditions, or even move ahead of them, and much of the influence which the laboratories have acquired in the textile industries during the last decade is simply the expression of the changes which have been taking place in those industries.

The present lecture is divided into three parts. In the first part I venture to indicate those features of the cotton industry which seem to me to have a salient importance. In the second part attention is directed to various improvements in the resources at the disposal of the industry—both of knowledge and of organisation—which have become available during the current century, since my first contact with the cotton growing side of it in 1904. Thirdly, some suggestions and speculations are offered with regard to the future. At all times the use of the term "the cotton industry" implies the growing and merchanting of cotton as well as the spinning and I stop short of the manufacturing and finishing end of the industry only because this transcends the limitations of my personal experience.

Salient characteristics of the industry as it exists

At the head of any list of the peculiarities of the cotton industry we may safely put its dependence upon unskilled labour. So far as the spinning side is concerned it is not very different from other spinning industries, which share with it the employment in large numbers of a type of operative whose maximum usable skill can be attained in a very short time from the date of first entering the industry. But in addition to this the limiting factor in the supply of the raw cotton is the labour available for the act of picking the ripe cotton from the plant; consequently, cotton can only be mass-produced in countries with a dense population relatively to the area under cotton. But dense population implies land hunger and high land values, whereupon the profitable cultivation of cotton becomes dependent on the attainment of high yields per acre. The obvious implication is that cotton can never be a cheap raw material; at the present day its cultivation on the valuable soil of Egypt, (whose annual rental would purchase the same area in England outright) is a much better business proposition than its cultivation with low yields in the United States. Since the world population will continue to increase, and the demand for food products to increase with it—once the temporary aberration of agriculture due to the substitution of internal combustion engines for food-consuming horses has passed away—it seems fair to assume that cotton of low quality and low price will presently be not worth growing, and that cotton production will concentrate on the higher qualities; the ready saleability of Egyptian Uppers during the

recent depressed state of the industry is a partial example of this tendency.

We have stepped beyond the limits of this first part of my lecture and must return to look rather more closely at my description of the bulk of cotton spinning labour as "unskilled," a description to which some of my hearers have possibly taken exception. To any such sceptics I would advise a reference to the paper communicated by the late Mr. J. W. McConnel to a former conference of this Institute held at Nottingham, when he utilised the vital statistics and the census data for occupational ages to show how ephemeral was the concern of most individuals with cotton spinning employment, the men scarcely less so than the women; the commonest age of employment for both being only eighteen years. This flight of the men from the industry is due to the small chance of obtaining promotion by moving up to more highly skilled work. I have formerly commented, in a letter to your *Journal*, on the remarkable statistical result revealed by a joint "Discussion on the shortage of Juvenile Labour" held in Manchester in 1924 at the Institute; in that discussion certain figures were authoritatively stated as representing the number of operatives required; on matching that figure with Mr. McConnel's results I found that the cotton industry could only obtain its fair share amongst all the Lancashire industries *if* the school leaving age were put back to eight years old; this was the actual minimum age fixed by law in 1830, when the cotton industry assumed its present form. Under these circumstances it is inevitable (whatever may be the temporary hardships of displaced employees during the change) that certain changes will develop in the mechanical equipment of cotton spinning, leading to a reduction in the number of separate mechanical processes, to a consequent increase in the complexity of the machines and to a wider gradation of skill in their supervision.

At the present day the industry may be described as having too many machines, which machines are individually too simple, with one exception, the mule; that it could utilise more complex machines satisfactorily is demonstrated by that exception.

The next salient feature of the industry is the fact that no two cotton hairs are exactly alike, even when they have grown on one and the same seed. Although uniform cotton is very desirable, it is quite impossible to obtain it, and the most uniform cotton which the best grower can supply is a complex mixture of hairs which differ enormously in their length, diameter, wall thickness, strength, and slipperiness. We shall see later how this situation may be dealt with in the future, but at the present day it is met by using a technique of blending, or mixing, in order to obtain a raw material of constant average properties; the other textile industries are able to employ the converse process of sorting, whether in silk, wool, or flax, simply because their raw material is big enough to be handled; I do not claim that this hand sorting is complete, and that there are not residual differences within their sorted classes, but it is clear that a fair analogy to the cotton industry would be provided by a worsted industry in which not only were the entire fleeces of sheep fed into the mill, but these entire fleeces were often of several different kinds, mixed in proportions which were varied from time to time.

These two characteristics taken together seem to me to differentiate the cotton industry very clearly from most other forms of industrial endeavour, and thereby to define the lines along which it may be expected to develop or shrink, in the future. They may be summarily described as a state of dependence upon unskilled labour, and upon unclassified raw material.

One minor salient deserves comment. Cotton was initially a raw material for making a cheap substitute textile, in the early stages of the industrial revolution.* It passed onwards to produce textile fabrics with virtues of their own in strength and fineness; indeed, it thereby reverted to its previous use in the native industries of cotton-growing countries. At the present day its use as a textile pure and simple, for covering purposes only, is rapidly becoming less

important, and the centre of gravity of cotton uses is shifting towards purposes which may be described as those of engineering. It is not a despicable engineering material; its tensile strength is comparable with that of mild steel, and no steel would endure the everlasting flexure undergone by the cords of a motor car tyre.

The status of the artificial fibres in relation to cotton is merely another aspect of this salient. It is often stated to-day that artificial silk has reached its limit of usefulness, that further improvements in it are unlikely, and that it will serve cotton for the future as an embellishment, not as a competitor. I am sorry that I cannot subscribe to this comfortable belief; it has been held throughout the twenty odd years during which I have been keenly interested in the possibilities of artificial fibres, and it has so far proved itself erroneous to such an extent that the world's output of artificial silk is now bigger than the whole Egyptian cotton crop. Whatever the appearances may be in England, the contents of the cosmopolitan shops of Cairo lend no evidence to such a belief. It seems to me far more likely that the past few years of competition between artificial silks and the fine cotton textiles has been a temporary phase, and the prospective victims of the artificial fibres are the inferior kinds of cotton and yarn.

But if cotton will continue to desert its proper textile employment in favour of engineering uses, this antagonism will not matter much. The cotton spinning industry of the future might be largely divorced from weaving, concentrating on the production of cords; it will be a fine spinning industry, working with fine cottons, but usually spinning them into coarse counts. My guess is—that the artificial fibres will be successful in their rivalry to the wrong kind of cotton spinning, but that the world demand for the best kind of cotton yarn will keep this modified form of cotton industry occupied for an indefinitely long future.

Extensions of knowledge and method during recent years

Twenty-five years have elapsed since I first visited Manchester in the capacity of a botanist who, being concerned with the genesis of the supply of Egyptian cotton, was finding it necessary to learn something about the consumption. The process of learning was difficult to a degree which is almost incredible to-day. The traditional secrecy of the industry made one's chance of learning anything contingent on the chance of meeting one person here and another there who would give second-hand information. There is still far more secrecy than is profitable, but my fortunate successors can get on to lines of communication where they learn more in a day than I could learn in a fortnight, and they can use the shorthand of scientific terminology for the purpose.

There has been a revolution. For that revolution, and for the profit which has accrued to the industry in consequence, the industry is primarily indebted to the late Mr. John Wanklyn McConnel. As a cotton spinner of the third generation, with a knowledge of home agriculture, and an extensive experience of cotton growing overseas, he was the first to appreciate the inevitability of close liaison between spinner and grower, and to realise how little real knowledge of the cotton was to be found underlying the industry's intimate knowledge of the machines. At a later stage we jointly discovered similar ignorance of the yarn, and the generalised efforts which the Textile Institute had begun for all textiles were by him specialised and extended to both sides of the cotton industry. Starting from a Board of Trade Committee on textiles, he became the moving force in the crystallisation process which formed the British Cotton Industry Research Association, and then the Empire Cotton Growing Corporation.

So many changes have taken place since the century began that it is not easy to find a grouping for them which will include both the greater and the less. Nor is it easy to know which is which; some discovery apparently of trivial importance, may bring about a change in outlook which is of enormous importance. When I climbed down a hole in the ground among the cotton

plants in a garden on the Gezira at Cairo, in 1908, armed with a needle jet of water from a force pump, and made myself very muddy by washing out a cotton root until I had tracked it to a depth of seven feet below the surface, I could appreciate that this interesting observation would affect our ideas about suitable soil conditions, but I failed to realise that it would permeate our whole outlook on every cotton growing problem, and would be at the present time of Imperial interest in the Sudan.

On the whole, having regard to the greater growth capacity of an idea (though itself derived from a grouping of facts) over and above the potentialities of a fact, I am inclined to select two ideas from the list of miscellaneous jottings which I made when preparing this lecture, and to give them pride of place among these extensions of knowledge in the cotton industry. One is the late Prof. Johannsen's idea of "pure lines," the other is the idea of translating all cotton problems into terms of single cotton hairs.

I put the work of the late Prof. Johannsen of Copenhagen in the first rank of discoveries affecting the cotton industry because of the certainty which it has given to the seed supply whereby our raw material is grown. Johannsen's work is, in one sense, quite secondary to that of Gregor Mendel, whose law of gametic segregation in heredity made the clear-cut conception of pure lines a possibility. But the practical utility of knowing that, after going through all the operations of cotton breeding (whether by direct application of Mendel's law, or by partial application, or by statistical treatment and rule of thumb, or by all together) one could eventually obtain a family of plants which were all alike and would remain alike indefinitely from generation to generation, has been immense. It has enabled us to escape from the bugbear of "varietal deterioration." It has encouraged us to search for the simple causes whereby foreign individuals find their way into such pure lines when a large number of plants are being grown under field conditions. It has enabled us to demonstrate that these simple causes of contamination make it quite impossible to keep varieties pure in bulk, and so it has compelled us to develop the concept of seed renewal from nucleolus stocks, these being small enough to receive such treatment as will preserve them from all these causes of contamination. It has led thereby to a treatment of the seed supply problem which is more akin to civil engineering than to conventional botany, and at the present day we utilise cold storage to preserve nucleolus seed, filmy gauze cages of stainless steel to exclude foreign pollen from the nucleolus plants during the first year of propagation for renewal, special seed-sowing methods to hasten us over the dangerous second year when the risks of contamination are enormous, and scientifically considered arrangements for the following years. Any modern variety of cotton which has once been reduced to the state of a Johannsen pure line is a permanent possession of the industry which need never be lost, and can be withdrawn from supply or reintroduced, as the demand may require.

The change in outlook brought about by the pure line concept is well exemplified by the wonderful set of statistics obtained in the working of the seed control law in Egypt. These figures cover every sack of seed sown in the country, and entail the examination of representative samples from about a quarter of a million tons of seed annually. The facts demonstrated on this enormous scale do not leave the slightest loop-hole for the old vitalistic attitude towards seed supply; they not only show that all the theoretical implications of Johannsen's work are true in the full glare of everyday practice, but they have recently shown the plant to be so consistently truthful in its behaviour as itself to reveal the frauds practised by some commercial firms who, to put it politely, are still believers in vitalism.

I hope my listeners will forgive me the egotism of claiming that our modern method of formulating cotton problems in terms of the single cotton hair is also important, seeing that it is my own contribution. The single hair is the

fundamental unit, and the properties of a bale of cotton are those of its constituent hairs—although the number of these in an Egyptian bale is about fifty thousand million.

My point of view in doing this was not original, but was a logical development of earlier experience in agriculture. Having passed from the study of individual plants in cotton breeding to the study of populations of plants in field crop, it became obvious that the same techniques could be applied to the crop if the statistical observations made upon the crop were computed down to represent the behaviour of an average plant. This simple procedure at once broke down the arbitrary distinction between agriculture and botany, and proved to have all sorts of unexpected conveniences. Similarly, the single day was another obvious natural unit in which the behaviour of these average plants must be recorded. So it became a merely logical step to pass on the same procedure to cotton spinning, and to deal with spinning problems in terms of their own natural unit, which is, moreover, a structural and physiological unit of the plant.

I cannot delay here to dwell on the great advances of scientific knowledge with respect to the life history and structure of the cotton hair itself during the last two decades. This tiny object has proved itself to present an enormous field for studies pioneered by Mr. Hancock and myself, wherein plant physiology, microscopy, and genetics are still establishing closer and closer liaison with statistics, with elementary and atomic physics, with organic and colloid chemistry. Instead of repeating a story which is already old, I would like to take the opportunity of reporting some recent discoveries made in conjunction with my colleagues C. H. Brown and Abd el Ghaffar Selim at Giza. They have found a case which is suggestive of Mendelian segregation of a fine cotton from a coarse one; also we have quite good evidence to show that the quantity of secondary cellose deposited in the hair is relatively constant and independent of the diameter of the hair cell; various fragments of evidence which have only been waiting for co-ordination give us clear indications that the outer layers of the hair are in a state of tension, while the inner layers of an excessively thickened hair are in a state of compression. I must resist the temptation to dwell on the practical implications of these apparently trivial facts.

Among many curious consequences of this attention to the individual hair I may specify our realisation of the relative lack of importance which can be attached to length of staple, in comparison with the other hair properties. In the past there had been no technique for measuring any other property than length, which is the only one appreciable by the naked eye, and an altogether disproportionate importance has been attached to it in consequence; length is an advantage when other things are equal, but we are now completely familiar with many cases where marked inferiority in length is accompanied by marked superiority in spinning, because the other things are not equal.

Another consequence is a realisation of the unexpected range of possibilities which different varieties present, or could present, in respect of fineness. Not only must we separate fineness by weight from fineness by size, but we can also have different types of hair within the same fineness group; for instance, a wide but thin walled ribbon of the same hair weight as one which is much narrower but possesses thicker walls, and these differences are recognised instinctively by spinners as presenting peculiarities in work.

Emerging from these hair studies there is another queer inference. I suggested five years ago that it might be easier to advance rapidly in the solution of fundamental spinning problems if the experimental spinning mill were located in the cotton-growing country, so that the various possible kinds of raw material could be prepared to specification by the botanist and agriculturist. Since then I have returned to the growing of cotton in Egypt, and my speculation has become a definite conviction. We find that the true diameter of the hair cell, and the intrinsic strength of the cellulose wall are definite varietal characters;

the form of the cross section of the hair is more susceptible to fluctuation, but is characteristic on the practical average. The results of spinning tests (made for us in Europe) from the same variety grown in different parts of Egypt over a length of eight hundred miles, and of different varieties grown in the same locality, show evidence of the difficulties under which students of cotton spinning must labour when the raw material of their experiments is not personally familiar to them; for example, we know that no reliable data can be obtained in the comparison of one variety with another unless the two have been grown in the same spot at the same time on soils which are made identical by the system of interlacing plots on a chequer board. A proposal to establish an experimental spinning mill and its technological laboratory was approved by the Egyptian Government some three years ago, but the project is not one to be undertaken lightly, on account of the enormous diurnal variation of humidity and temperature in Egypt, which necessitates highly specialised arrangements if fine spinning is to be attempted successfully. The delays in reorganisation of the other branches of our work have so far prevented me from giving this project the whole time attention which it would demand, but each additional year makes it more obvious that a technological organisation which studied both spinning and growing, in the same place and under a unified control, would be of much greater value than the sum of any two separate organisations doing the same work.

I have dealt at some length with this point because the results which have so far been achieved in the central problem of cotton spinning are somewhat disappointing; I refer to the prediction of the properties of the yarn from knowledge of the properties of the cotton. Much progress has been made, but we are still far short of the broad generalisations which will eventually be obtained. Indeed, it has taken the technologists a surprisingly long while to realise the centrality of this problem; I had been working on it myself for five years when I ventured to offer it as such in a committee which was discussing programmes of research work ten years ago; it was intimated to me that there was no such problem, so—somewhat crushed—I said no more, and returned to work on it. Five years later it began to attract notice, and last year I heard it described as the fundamental subject for cotton spinning research !

It is not without significance that during this period we have seen substantial practical advances in the construction of yarn, exemplified by the way in which it has become possible to build tyres from Uppers, which will do the same work as was formerly done by Sakel. I have already mentioned how Mr. McConnel and I came to realise our ignorance of the properties of yarn, and although that ignorance is decreasing, I venture to think that our knowledge of the cotton is still far in advance of our knowledge of the yarn. It is true that yarn is a complex structure mechanically, by no means easily submitted to rigid analytical treatment, but an astonishing commentary on our erroneous treatment of its problems in the past is provided by our failure to realise that the singles yarn is not a finished product. Just because it is the end-stage of cotton spinning we have regarded it as a product: yet in reality it is no more than a convenient form in which to carry the cotton away to the next process, whether for doubling or for weaving, just as the scutcher-lap is a convenient form of presentation to the card. We should not dream of attaching anything more than a minor importance to the properties of cotton as manifested in a scutcher-lap.

Thus it follows that the nearer we approach to the completed fabric or cord, the more do the properties of the cotton itself assert themselves, and although the substitution of an inferior cotton becomes possible through technical improvements in methods of construction, yet the better cotton will give the better result when other things are equal. The essential unity of interest between the technological problems of spinner and grower is thereby emphasised once more.

The general position with regard to these changes in the technology of cotton spinning during the past two decades may be summed up by the statement that we have emerged from the stage of obsession by the machines themselves, and are concentrating our attention on the reactions of the cotton to the machines. Our former obsession by the machines was a natural survival of the justifiable pride in machinery which marked the industrial revolution; we are now passing into a stage when physical science is taking control.

It would not be fair to conclude this section of my lecture without some further reference to the advances in agricultural technology, over and above the advances in seed control already discussed. A bird's eye view of these may be obtained by a glance through the annual reports from experiment stations published by the Empire Cotton Growing Corporation, especially the early ones. The increase of knowledge has been so great that whereas cotton was one of the least-understood crops at the beginning of the century, its reactions to conditions of cultivation are now more fully comprehended than those of any other crop, not excepting such familiar friends of man as the wheats and barleys. I like to imagine that this is largely due to the lucky conception of the crop as a multiple of the average plant, to which I have already referred. It is also due to the convenience with which records of growth, flowering, and fruiting can be made and presented as plant development graphs, showing the life-history of the average plants throughout the growing season; the exactitude which can be obtained in this way, when combined with the technique of chequer-plots, is almost incredible to those who have not been brought up among such work; a yield-difference of 5% between two different agricultural treatments can be demonstrated with certainty, and analysed out into its components. The essence of the matter is that we are no longer content to deal with total yield, but only with analysed yield, and it is now a matter of everyday experience to find that two sets of conditions may both arrive at the same total yield, and yet do so by completely dissimilar paths.

Whereas I had great difficulty twenty years ago in persuading would-be experimenters that the practical difficulties involved in handling large numbers of small chequer-plots, as first advocated by Wood and Stratton, and in taking plant-development graphs from them, were by no means insuperable, and were well worth while, to-day we are seeing this technique extended to such an extent that not only are groups of 125 plots handled with two variable factors involved, but three-factor and four-factor experiments are being conducted successfully.

Since my return to work on the experimental farm at Giza near Cairo, where experimental cultivation has been in progress since 1898, we have seen our way towards eliminating a great deal of the uncertainty caused by local variations of soil, which at present can only be counteracted by averaging out on repetitions of small plots. Just as the plant development graph system has changed the probable error of any one plot into an error which is tangible and no longer hypothetical, so the study of data from crops grown on the same spots in successive years has shown, when combined with study of the soil conditions on those spots, that the probable error due to soil variation is also tangible; groups of plants separated by distances of only ten meters are showing the same differences in 1930 that they showed in 1912. It is becoming possible, given sufficiently intimate knowledge of soil variation in any given site, to dispense with much reduplication of plots and apply corrections for soil variation instead. But the extent of this variation is enormous, since the deep-rooted habit of cotton plants makes it necessary to take into consideration not merely the top foot of soil, but also the soil which lies two metres and more below the surface. My colleagues at Giza have found that the root races downwards under favourable conditions at a rate of a metre a month, and any arrest of that development exercises an immediate and irreversible check on the development of the aerial portions of the plant, whether such arrest be due to meeting a waterlogged layer, a layer of

comparatively dry soil, or a layer which contains toxic substances, with or without deficiency of oxygen, even when such a layer is more than two metres underground.

Dr. Templeton has also demonstrated a most extraordinary condition of root-suicide, where the drain of water into the root from a stiff clay layer causes the clay to crack in all directions and so smashes the roots.

The observational difficulties involved in these studies of the underground portion of the cotton crop are almost insuperable, but their very difficulty makes the problem the more interesting, now that we are realising more completely how important and enormous is this hidden portion of the cotton crop.

Speculations concerning the future

It may be futile to speculate on the future possibilities of cotton technology, seeing that such speculation involves an initial assumption that the industry itself will survive the pressure of industrial and agricultural competition. But speculation tempered with a trace of scientific justification in an attractive occupation, and certain considerations embodied in the two preceding parts of this lecture make it almost imperative that I should complete the process of committing myself.

Following the industry from the seed bed to the doubling mill we can see reason to expect an intensification and specialisation of the agriculture of cotton, with a concomitant disappearance of the inferior kinds from the world's markets. Such inferiority will not be judged merely in terms of length, but the short staples will probably disappear, and (although the general tendency to increase the length of staple cultivated will probably continue) it is likely that exceptionally long cottons will also be at a disadvantage. The structural advantage given in yarn by each additional millimetre of length is a diminishing quantity, and it may well be the case that the convenience of being able to feed all kinds of cotton into similar roller settings will eventually lead to a kind of standardisation of length, leaving the differences of demand to be adjusted in terms of fineness, because such differences in fineness call for relatively small alterations in machine setting compared with those demanded by length differences.

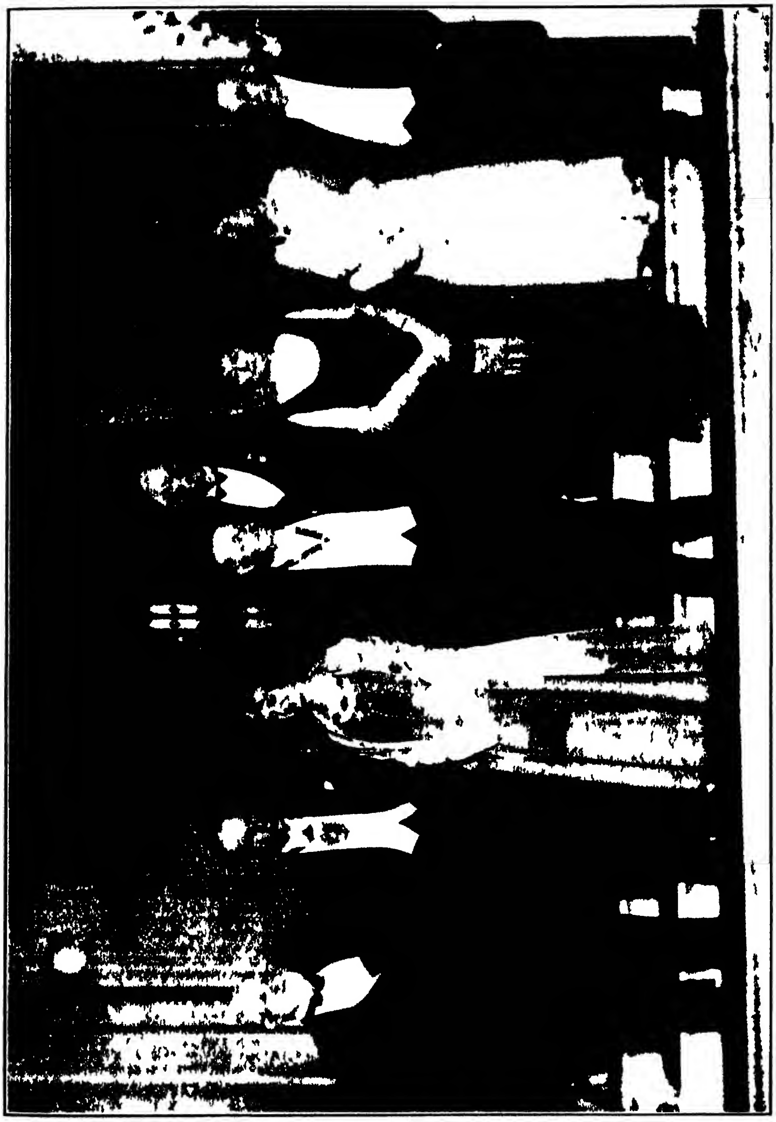
The possibilities of cotton breeding for quality have scarcely been surveyed as yet, while even now it has been found possible to breed for increased yield in such a specialised cotton-producing area as Egypt.

The better understanding of the physiology of the crop is leading to increases of yield from the same variety on the same land, again in Egypt, which—as we have already seen—implies that other cotton-producing countries must either follow suit to an extent comparable with the intensity of their food production demand, or abandon the growing of cotton in order to feed their increasing populations. In the case of Egypt, where the available area is strictly limited, and can only be increased by about one quarter at the most, I estimate that the present eight million kantar crop might eventually reach fifteen millions by such increase combined with intensification of culture, under the limitations imposed by agricultural, economic, and social requirements. The possibilities of other countries must vary with their local conditions, but among these I place very high the stability of their climate from year to year, leading to a reasonable certainty of an even-running product from season to season.

Failing the development of extensive applications of the sorting technique, to which I shall presently return, I can see no future for miscellaneous and unstable cotton crops.

The limiting factor of labour in the picking operation is most serious, and presents a problem for which no solution is yet evident. Cotton picking machines have been devised by the dozen, all reasonably satisfactory in operation. A few years ago we saw the picking process cheapened in America by not picking at all, but merely tearing off all the bolls with a "sled," and spending more afterwards at the ginnery in cleaning up the collection of rubbish thus gathered along with

Coming-of-Age Celebrations



Mr J W. Nasmith — The Lord Mayor and Lady Mayoress — The President and Mrs Dobson — Mrs. and Mr F Nasmith

The Institute Reception. Midland Hotel, 22nd April 1931

the cotton. It was a paying proposition temporarily, but unfortunately it is irreconcilable with the inevitable tendency of the industry to specialisation, which demands clean cotton from the grower, to such an extent that certain very highly specialised spinners will pay far more for high grade raw material than it would cost them to clean up moderate grades to the same level. Part of this latter anomaly may be due to the fact that grade is, on the average, closely associated with quality; low grade cotton is usually cotton which has remained too long on the plant and been weakened and tarnished in consequence. It is possible, and I hope to obtain direct evidence on the point, that pickings taken at very short intervals to ensure the minimum loss of quality from this cause, might be taken by some machine so roughly that their grade was low, and yet the cotton would be as good as the highest grade cotton except for the difference in waste loss. Whether this waste loss would balance out the economies in picking costs remains to be seen, but it is a possible line for economic research. For the moment it is clearly the case that cotton is picked far too infrequently, even in Egypt where far greater uniformity of lots could be obtained by short period picking, and it is also clear that no mechanical method can obtain the high-grade lots for which the spinner is willing at present to pay more than they need be worth, though probably not more than they happen to be worth under the present agricultural and commercial conditions. Another factor operating against mechanical picking is the high density of planting which is being found necessary in order to obtain maximum yields, which high yields are obligatory in order that cotton may compete with the food crops; at the present day the optimum density in Egypt is double what it was twenty years ago, on account of pink boll-worm, and even in those days the plants were too close together for the convenient use of a picking machine. It would seem that the problem of the cotton-picking machine is more likely to be solved in the spinning mill than in the field.

The cotton picked in the fields passes thence to the ginner and the merchant, and we here find a phase of the cotton industry which has no technology, but only an expert knowledge. It is probable that some form of organised research will be found profitable here also, but for the present it is merely being infiltrated slowly with technical developments from above and from below, from the spinner and from the grower. I have already commented on the improved technological relations between grower and spinner, so that they can now to some extent discuss their common interests in the common language of science; that community of language is still defective so far as the merchant is concerned. Yet the part which the merchant can play in marring the best-laid schemes of the grower, or in failing to respond in the right way to the requirements of the spinner, is a very important one; conversely, merchants who keep in the current of technological advances can render most valuable services.

The average merchant still believes that the best seed to use is that which is obtained from the best-looking sample of cotton; he would not dream of using seed from a low grade late picking off one of our pure nucleolus stocks at Giza. A statistical demonstration of the fallacy of this belief on a grand scale is nevertheless on record. Even while preparing this lecture I was formally requested to collect prize samples from an agricultural show and propagate them in order to improve the Egyptian crop, although all the seed from which they were grown had passed through our own seed-control laboratories.

The International Federation of Master Cotton Spinners has taken a very strong line in the reciprocal case of mixing varieties of lint, not so much from the spinners' view-point as on account of the difficulties involved in the finisher's work when hairs which differ more than they need are undergoing treatment. It is common knowledge that an unscrupulous merchant can mix certain varieties together without any likelihood of the mixture being recognisable by the most expert judges; again we need extensions of our technology to supplement the judgments of hand and eye.

The development of standardisation in other industries is affecting the merchanting of cotton. Not only have we the demand for standard specifications in the matter of varieties, which will become more insistent as the improved control of seed supply renders the varieties more sharply distinct from one another, and in its turn necessitates greater exactitude in the commercial handling of the seed of each, but the standardisation of moisture content is almost an accomplished fact for Egyptian cotton. The nineteen-year-old discussion on this matter has revealed very clearly the need for more technological equipment on both sides.

So, contemplating a spinning industry which is being supplied with correctly specified and standardised raw material we pass to my final speculations on the form which cotton spinning will take in the future.

At the beginning of the process I expect developments to take place along lines first suggested many years ago by Mr. A. S. Pearse on first becoming acquainted with my Sorter mechanism. It seems absurd that the orderly arrangement of fairly parallel hairs which is accidentally achieved on the roller of a McCarthy gin should be recklessly thrown away by stuffing the cotton without any order or arrangement into a conveyor and so into the press. In an experimental plant for spinning-test work, I should feed high-grade cotton almost direct from the gin to the card; how the same result might be achieved in commercial practice is well worth study.

The absence of any technique for bulk sorting of cotton into classes characterised by different lengths and fineness was mentioned at an earlier stage of this lecture. To a slight extent the card and comber may be regarded as sorting appliances, though only secondarily to their other functions, but there is no such prior separation into classes as the other textile industries can effect. I have demonstrated experimentally that such sorting is mechanically possible for length differences, but the practical result of spinning such sorted cotton was to show that the long-cherished distinction of length was relatively unimportant; speaking roughly, a cotton which is twice as long makes twice as strong a yarn, which is insignificant in comparison with the effects predictable as the result of sorting for fineness, if and when that is accomplished. The everyday achievement of length sorting can therefore afford to wait until fineness-sorting can take place concurrently with it. It needs no effort of the imagination to realise what this would mean to the industry in the matter of making badly-grown supplies available for good spinning, though even then we should still be dependent on the seed supply for the provision of a high intrinsic strength in the hairs, because it appears (as already stated) that the true tensile breaking stress of the cellulose wall is a characteristic which is specific for each variety, and is only slightly affected by the conditions of cultivation.

Less remote than these possibilities of sorting are the possibilities of employing super-drafts, so that the transition from the finishing draw-frame to the yarn may avoid the successive passages of flyframes, with their concomitant labour costs. In collaboration with Mr. F. Hutchins I have demonstrated the possibility of satisfactory spinning direct from the draw-frame sliver into 100's count with a single super-draft of two hundred; there is a ring-spinning machine actually on the market which uses two stages of high draft on the same frame to achieve the same result; there are possibilities in physical research on the hair which might give us super-drafts by other means than mechanism. That super-draft machines would be complex and expensive is self-evident; some of their moving parts would have to be built to far higher standards of accuracy; more specialised operatives would be required to supervise them. But in order to pay for the machines and for the labour, we can draw on the money which at present we pay not only for the spinning machines but also for three sets of flyframes and for the labour which attends to them.

Still nearer to actual realisation within a very few years is the advent of a satisfactory continuous spinning machine. In this case not only is the theory

adequately worked out, but the simple practical means of accomplishing it only wait commercial development. I refer to the arrangement which I designated as the "Rule" frame, it being a ring frame with nearly all the good points of the mule. A frame built on these lines, namely, with a long stretch of freely vibrating yarn between the drafting rollers and the spindle, is already on the market as the result of quite independent investigations in Germany; curiously enough, this Hartmann machine misses an essential characteristic of my rule frame, in that it retains the unnecessary and disadvantageous constraint of a thread-guide. I have a strong belief in the possibilities of this type of spinning machine.

One might continue speculating on these possibilities indefinitely, but the four which I have enumerated are definitely the major possibilities of cotton spinning. It may perhaps interest my audience to know how these considerations have resulted in a practical project for the design of an experimental fine-spinning-test plant in Egypt, to which I have previously referred. The difficulties in the design of this are not confined to the provision of a thermostatic and hygrostatic building, which will level out the enormous diurnal variation of spinning conditions, but also include the provision of operative staff; it would be comparatively easy to provide staff which is accustomed to the manipulation of complex and delicate apparatus, but very difficult to create a small class of routine operatives. When it becomes possible to proceed with this project I intend to try to do it with only three machines. The building will of course contain laboratories for hair-testing as well as yarn-testing, and rooms for storage and grading under the same standardised air conditions. The ginning will take place in the cardroom, and the ginned cotton will be fed undisturbed to the card by suitable arrangements; the high grade of all samples cultivated for experimental comparisons makes this possible, and the direct comparisons required also enable combing to be avoided. The carded sliver after passing the drawframes will be condensed by rubbers for direct spinning by double high draft in the Casablanca type of machine, which will be modified from a ring frame into a rule. The project is necessarily experimental, but there seems every reason to think that, while evading the almost insuperable difficulties involved in attaching such a plant to a set of agricultural research laboratories, its deviations from conventional practice will rather intensify the natural differences from sample to sample, the detection and analysis of which is the object of its installation.

Certainly the time is long past when the cotton grower could depend on the hand and eye judgment of the grader in working out his experimental results and his development projects. I find the contrast with my pre-war experience in Egypt almost amazing in this respect; the Alexandria expert is now a valued collaborator, instead of being the Lord High Executioner, the only authority on quality, speaker of the last word on the choice of cottons to be propagated, and the ultimate court of appeal. I have elsewhere recounted some cases of conflict between graders' judgments and the real facts ascertained; since my return to Egypt I have quadrupled the number of such cases; but they are now being detected in a process of collaboration wherein the work of the grower, grader, and spinner are co-ordinated towards founding a system of technology for the merchant himself.

Lastly I would like to refer to the organisations which have already brought about these advances in cotton technology, and will eventually carry them further than the limits of my speculative moments. The material resources of the laboratory, the library, the experimental farm or mill, and the co-operation of farmer, merchant, and spinner themselves may be taken for granted as inevitable necessities. But the weakness of the system under which these resources become available for use, resides in the teamwork system, which is also inevitable, and is indeed not merely desirable, but invaluable; nevertheless it is as true in technology as in pure science and in administration, that teams and committees have no initiative, and that every constructive step has its origin in the personal initiative

of some one individual, more often a young man than an old one. It is rather characteristic of the British that their systems of organisation lose their first splendid flexibility and power of initiative as they increase in size, and I sincerely hope that this danger will be watched in the growing organisation of cotton technology. Another form of the same danger can be seen in more than one instance familiar to me, where a wide diversity of inter-related technological problems is pursued by independent efforts, lacking the co-ordination which brings all the different threads together, and builds up a picture of the wood in spite of the trees.

In conclusion I would express my appreciation of the honour conferred on me by your President and Council by inviting me to provide the Mather Lecture on this special occasion of our coming-of-age celebration, and I am glad that it has been possible to choose a subject which, in its mingling of mechanical, textile, and agricultural topics, is one which would have appealed to the founder of these lectures himself.

The Chairman said they were extremely obliged to Mr. Hancock for the sympathetic way in which he had read the lecture. Personally, he would like to have this lecture read again in five years to the same audience; he thought there was so much that was prophetic in it and so much that they would find realised.

Professor A. F. Barker, Leeds, then took the chair, and a lecture was delivered by Mr. A. Abbott, C.B.E., Chief Inspector of Technical Schools, Board of Education, on the subject of "Technical Education for the Textile Industry."

The Chairman said Mr. Abbott was to speak to them on the matter of education for the textile industry. As chairman, he would have liked to say a lot about the importance of this paper, but as time was late he would at once call upon Mr. Abbott.

TECHNICAL EDUCATION FOR THE TEXTILE INDUSTRY

By A. Abbott, C.B.E.

(Chief Inspector of Technical Schools, Board of Education).

When I undertook to read this paper my instructions were rather vague. I understood, however, that while I might speak generally on the subject of technical education, I ought to make special reference to textile education, since one of the main objects of this Institute is to raise and maintain the level of technical knowledge amongst those engaged in the textile industry.

I propose, therefore, to deal first of all with the general question of technical education, and then to discuss some matters affecting that branch of it with which we here are particularly concerned.

Until the Industrial Revolution, which took place 150 years ago, technical education, in the modern sense, did not exist. Practically all skilled occupations were handicrafts carried on in traditional ways and taught by successive generations of craftsmen to their apprentices. With the coming of power-driven machinery, and the progress of invention and discovery, the system of apprenticeship began to decay. A smaller proportion of workmen needed great skill of hand, and attention began to be devoted to the scientific principles underlying workshop practice; in other words, a tendency arose for skill to be transferred from the craftsman to the man engaged in producing the machine which was to supplant him. These circumstances led to a recognition of the fact that the complete training of an industrial worker may conveniently be divided into two parts—one of them given in the workshop itself, and the other entrusted to the school. The former part gives the workman manipulative skill, while the latter part, which we now term "technical education," aims at giving him a knowledge of the relevant scientific principles.

The necessity, or at any rate, the convenience of regarding a complete training for industry as consisting of these two parts, was clearly seen by the founders of the early Mechanics' Institutes a century ago. In the prospectus of the Manchester Mechanics' Institute, for example, it was stated quite definitely that it was not the business of the institute to teach workshop practice and to train carpenters, dyers, and other workmen in workshop operations, but rather to give them a knowledge of the principles underlying the practice of their occupation.

The promoters of the early Mechanics' Institutes appear to have started with very high hopes. In their day they had seen England—and especially the North of England and the district round Birmingham—transformed from an agricultural to an industrial country which was quickly to become "the workshop of the world." They knew that one of the main causes of this transformation had been the swift progress of invention and discovery; and they had noted that many of the far-reaching inventions had been made by unlearned men. It was accordingly quite natural for them to believe that further progress would be rapid and that the Mechanics' Institutes would contribute greatly to this progress by teaching working men something of the science related to their craft. Their hopes were, however, doomed to disappointment. The fact was that before the Mechanics' Institutes could devote their attention to teaching scientific principles, these principles had first to be discovered; and the process of discovery seems to have been much slower than was anticipated. Further, although mechanical inventions have often been made by men of little education, most important improvements can only be made, or their real value appreciated, by men who have had a prolonged scientific education.

Accordingly, technical education, as we now conceive it, made slow progress until considerable advances had been made in our knowledge of physics and chemistry. The practice of dyeing, for example, was necessarily to a great extent empirical until a much later period in our industrial history, since its scientific practice had to wait for a great increase in our knowledge of organic chemistry.

It was for these reasons that the development of technical education was delayed until the universities—and men trained in universities—had been for many years engaged in research in "pure science," that is, in the gaining of knowledge for its own sake rather than for the sake of utilising it in industry. This delay was inevitable so far as those industries which depend directly on the application of science to production were concerned. Moreover, technical education—in the sense of teaching scientific principles first, and then showing how they can be applied to industrial practice—cannot, even now, be regarded as having reached a high degree of development except in the case of those industries whose fundamental principles have been the object of study and research in universities for generations, that is, in engineering and its branches and in the chemical industries, including metallurgy.

There is, however, another group of industries in which the relation of workshop method to scientific principles has not been so fully explored as in the case of engineering and the chemical industries. The textile industries belong to this group, and the late application of science to them has probably been due in a great measure to the difficulties inherent in the scientific investigation of raw materials, which vary in type and quality according to their origin and their breeding, and have to undergo a long series of mechanical operations, and possibly some chemical treatment.

Whatever the reason may be, there is no doubt as to the facts. For many years the problems of the Textile Industries were not systematically explored by groups of trained investigators aiming at discovering the qualities of their raw materials and relating these to industrial practice. Even in the universities it

was not possible for the textile departments to carry their investigation of processes very far until more was known of the physical, chemical, and biological properties of the various textile fibres.

The necessary consequence of this delay to apply research to the industry was that the technical education provided for its personnel consisted mainly in a systematic account of the various operations and of the way in which these are modified to meet different materials and varying conditions, together with such instruction in calculations and drawing as is needed for carrying out and supervising the operations.

It is not suggested that the technical education of students engaged in the textile industries is less worthy than that provided for, say, students of engineering, or that it makes smaller demands on their diligence and ability, but only that it is, from the nature of things, in an earlier stage of development; it is, in fact, less quantitative and more qualitative than the instruction provided for engineers.

And here I should like to say that, looking back at the work of the early teachers of textile subjects—Ashenhurst, Fox, Myers, J. T. Taylor, and Neville—I say nothing of the men who are happily still with us—it is impossible not to admire the ability, energy, and enthusiasm with which they not only executed their difficult task of creating a system of textile education, but also secured the general interest of the various branches of the textile industry in the work they were doing. In this they were greatly aided by the encouragement and material support of the City and Guilds of London Institute.

Influence of Scientific Research Associations

During the last fifteen years a new factor has arisen which has already influenced textile education and may influence it still more, and that is the movement for organised scientific research on a co-operative basis. This started in Yorkshire and it was mainly due to the initiative of Sir James Hinchliffe that a group of Woollen and Worsted spinners and manufacturers undertook to encourage the scientific investigation of the problems of their industry. At a later date this association was merged in the Wool Industries Research Association, with its headquarters at Torridon, Leeds, which was set up in co-operation with the Department of Scientific and Industrial Research.

It is worth while to record also that the British Cotton Industry Research Association, with its headquarters at the Shirley Institute, owed its start to a proposal made by Dr R. H. Pickard to the same Government Department that he should conduct with their help an investigation of the process of sizing cotton yarns. At the time when he made this proposal there was no "million fund" for aiding and encouraging scientific research conducted by Industrial Research Associations. It was only after a conference held in the Lord Mayor's Parlour, in Manchester, in July 1916, between representatives of the cotton industry and of the Department of Scientific and Industrial Research, that the State definitely undertook to make grants in aid of these Associations. Research Associations were established at a later date by the silk industry and the linen industry, and it seems to me a matter for legitimate pride that the textile industries have been, amongst all industries, those which have adopted the plan of co-operative research most fully.

If we compare the organisation of research and education for the two groups of industries which I have mentioned, a very important difference is now obvious. Since it is the function of the university both to gain new knowledge and to train students, the universities have performed a double function for the engineering, metallurgical, and chemical industries. But in the case of the textile industries, the gaining of new knowledge by scientific investigation is in the main entrusted to the Research Association, while the training of students is undertaken either by schools which, as a rule, do very little research, or in universities, where textile investigation over a wide field has only recently become possible owing to the

increase in the volume of scientific work on the physical, chemical, and biological aspects of the textile industry.

In view of the close connection between research and education, since both are concerned with knowledge, it seems important that the Research Associations should have some intimate relationship with the schools. What form that relationship should take is not yet clear, but it is very satisfactory to note that both at the Shirley Institute and at Torridon, the Research Associations have welcomed the holding of courses of instruction for teachers of textiles, and that at the former Institution the teachers of the most important cotton schools are associated on a committee with which the Director is in regular consultation. Without close co-operation between the Research Associations, the schools, and the universities, there is a serious risk that the work of all of them will be hampered.

Although I have discussed the Research Associations at some length, since it seems to me scarcely possible to over-emphasise the fact that their establishment has introduced a new and most important factor into the problem of textile education, it is with this latter problem that I am concerned to-day. In the past, the schools have usually provided courses in spinning or weaving, closely resembling one another in each textile area, to be taken by all students, whatever the type or grade of their work. It seems likely that the schools will have very soon to consider whether they are justified in retaining this plan. A modern tendency in technical education is to consider whether students cannot be divided into groups having somewhat similar educational antecedents and possessing homogeneous educational needs. For example, it was formerly customary to provide for students engaged in engineering works, whatever their occupations might be, a fairly uniform course of instruction, which included such subjects as machine construction, mathematics, applied mechanics, and heat engines; at the present time courses differing considerably from these are being devised for moulders, pattern-makers, machinists, and the like. There is thus arising a differentiation in the types of instruction provided for recruits to the different branches of engineering; and, further, there will ultimately be different grades of instruction suitable for artisans and foremen, for works' managers, for salesmen, and for designers of machinery. Does it not seem likely that instruction for the textile industries will ultimately follow along the same lines ?

There must be at the Research Institute and in the universities well-trained scientific workers who appreciate thoroughly the problems of the industry; there must be well-educated mill managers of broad outlook; and there must be competent overlookers dealing with sections of the operations without necessarily having a full knowledge of the whole of the operations of the mill.

Essential Managerial Qualifications

No one who has visited a Research Institution for the textile industries can have any doubt that it should be staffed, in the main, by men whose main qualification is their knowledge of science. They must have acquired such a familiarity with the principles of the science underlying workshop processes as will enable them readily and effectively to deal with the particular set of problems presented by the textile industry; further, they must have the "team spirit," as it is essential that they shall work together harmoniously for a common end. It is natural that the industries should look towards the universities when they are seeking men with this knowledge and this attitude of mind, although certainly they should not regard the university as the only source of supply of suitable men. From what I have said, it will be clear, I think, that in my view it is not usually the textile specialist that is needed for advanced research in textiles, but rather the man whose undergraduate course has been in pure science or in engineering, and who has made some post-graduate study of textile problems. But these are high matters; and perhaps I am not competent to hold an opinion worth mentioning on them.

With regard to the mill manager, it is no longer sufficient for him to know thoroughly—as he most certainly does—existing practice. He has two other important duties—

(*a*) He must be able to understand the exact bearing on day-to-day practice of a new piece of knowledge communicated to him by his research organisation and must be ready to modify his own practice if he sees that advantage will result.

(*b*) He must be skilful in distinguishing in his own daily experience those problems which should be referred to the Research Association for their solution, and the other minor difficulties which should be solved by him and his staff.

These two additional demands which are now beginning to be made on the organisers and controllers of textile factories are such as to cause every one of us who is concerned with textile education to reflect on the present system and to ask himself whether, in fact, the schools are providing a sufficient number of men with those essential qualifications which are more conveniently and effectively developed by education than by works' experience; and even if we do not ask ourselves the question, we must not be surprised if it is put to us by the industrialists who have for a dozen years been contributing to scientific research. What is our reply to be ? I think it must begin by making it clear that the question is not one for the textile schools alone, but one with which nearly every type of educational institution is concerned; and, further, that if there is any failure of the educational system to meet adequately and quickly the new demands, part of the responsibility for this rests on the industry itself.

It is obvious that the qualifications needed by a man who is to control successfully the whole of the operations of a modern textile factory, using to the full all the relevant available knowledge and submitting regularly to his research organisation the more difficult problems he encounters, cannot be acquired without a prolonged training. They include not only a sound knowledge of such subjects as physics, chemistry and mechanics, and an intimate acquaintance with the properties of raw materials and existing processes, but also such qualities as self-reliance, resourcefulness, and great mental alertness. It seems desirable therefore that a man who aims at becoming the organiser and supervisor of a modern mill, or of a group of mills, shall have received a full-time education up to the age of at least 16; that is, he should have a broad foundation of general education, including some knowledge of science, on which to build his further studies.

This suggestion may seem rather revolutionary, when the present method of recruitment in the industry is considered; it is to be remembered, however, that during this century the whole system of education in this country has been developed and greatly modified. Until the Education Act of 1902 came into force, there was not in England a comprehensive system of secondary schools, and nearly all recruits to the textile industry entered it from the elementary school at the age of 13 or 14. The more able and diligent of these recruits equipped themselves by attendance at evening schools and by private study for responsible posts, and it is to men with this kind of early career that much of the credit for maintaining the efficiency of this important group of industries belongs.

During the last few years it has become customary throughout the country to examine all children in attendance at elementary schools when they reach the age of 11, and to transfer the more capable of them either to central schools with a leaving age of about 15, or to secondary schools with a leaving age of 16 or more. Accordingly, any industry whose successful practice demands the application of science to its problems, must take account of this great change in the educational organisation of the country. If it continues to recruit its newcomers mainly from the elementary school, and to rely on finding among them in the future its most responsible officers, its welfare is likely to diminish considerably.

The rate of development of education beyond the age of 14 may be gauged by observing that there are now at least 300 Central schools in England and that there are more than four times as many pupils in grant-aided Secondary schools as there were 25 years ago.

Two comments on the present state of affairs should be made. In the first place, no one wishes to suggest that the boy whose full-time education has finished at 14 should not be encouraged and helped by every possible means to equip himself for the higher posts in industry in exactly the same way as in the past; and, in the second place, it should be clearly understood that the recruitment to the textile industry of youths with a preliminary education which is both broader in content and longer in duration does not mean that they would come from a different social stratum, but only that they would travel by a different path.

There is no doubt that the syllabuses and methods of instruction in textile schools as a whole are improving; but the work of the schools would be greatly helped and indeed placed on a higher plane if the teachers could assume with certainty that their more ambitious students had received the sound preliminary education now provided so widely in central and secondary schools.

Requirements for General Technical Training

In considering the education to be provided for the overlooker or departmental foreman in the textile industries, it is again of interest to make a general comparison with the technical education provided for the engineering and chemical industries which, as I have already indicated, have an obvious and direct scientific basis, and have been greatly aided by the work done in universities. One result of this has been that engineering instruction, even in our ordinary Evening Technical Schools, has been modelled rather closely on that given in universities, although the great bulk of it is on a lower plane and has a narrower scope. The curriculum usually includes mathematics, engineering science and machine construction for nearly all students of 16 or more; in other words, it is normally so constituted as to be very suitable for the youth who is ambitious to occupy a post carrying with it a responsibility different from that of the craftsman. There are, however, many signs that greater attention will in the near future be paid to the needs of the craftsman, whose ambition is to excel in his craft rather than to enter the drawing office, or to qualify for some other post not immediately concerned with workshop processes.

Textile education, as I have already said, began at the other end and had in view at the start—and indeed for many years—mainly the needs of men engaged in carrying out or supervising the actual operations of manufacture. It is only recently that the need for men with a training in general science has arisen in that part of the textile industry which is not concerned with the finishing processes.

So far as one can judge, it is likely that, at some time in the future, education for the engineering and the textile industries, having started from opposite points and pursued very different paths, will arrive at approximately the same systematic organisation, which will provide adequately for the educational needs of all the various types and grades of workers in both industries. What is obviously necessary in both cases is full co-operation between the industries and the schools; and there is every reason to believe that this co-operation will be harmonious and complete.

To pursue the comparison between education for engineering and for textiles a little farther, there is no doubt that each of them is, within the limits I have mentioned, satisfactory. A competent American observer, who visited typical Technical Schools both in England and in most of the countries of Western Europe three or four years ago, stated emphatically that he had found nothing so good anywhere as the instruction given to engineering apprentices in our English technical schools, and I am confident that the same judgment could properly

be passed on that part of textile education to which we in England have devoted our attention. The work now being done in our textile schools is undoubtedly admirably adapted for the education of men who are to exercise a rather narrow range of activities. The main criticisms of it that can properly be made are that, in concentrating attention on a particular group of operations, it does not always deal sufficiently fully with those operations which precede and follow this group: and that, as a rule, attention is devoted to the working qualities of only one kind of textile fibre. There can be no doubt that it is of advantage to any man engaged in the production of yarns to know something of the operations through which these will subsequently pass, or that it will be of use to a man engaged in a weaving business to know something both of spinning and of the various finishing processes: similarly, it is of interest and value to a man concerned with the cotton processes, for example, to know something of woollen and worsted processes.

Developments in Textile Technical Education

I have now discussed the kind of qualifications which, as it appears to me, the three most important groups of men specially trained for work in the textile industries should possess, if these industries are to hold their own in the face of increasing competition; and I think it will be realised that I contemplate the necessity of certain developments in the system of textile education intended to ensure a more scientific training for the men who are to hold very responsible positions in the management and control of textile factories. It does not seem probable, or even desirable, that these developments will take place in a large number of schools, but rather that the most important institutions will be called upon to devote their attention to teaching "textile science" rather than "textile technology." Necessarily the students who undertake the study of textile science will have some preliminary knowledge of mathematics, physics, chemistry, and mechanics; they will include in their studies the physical and chemical properties of all the textile fibres commonly used in the industry; the conversion of these fibres into yarns and cloths; the chemical and physical treatment of yarns and cloths in order to produce marketable goods; the analysis and testing of raw materials, yarns, and fabrics; the statistical treatment of experimental results. Throughout the study of processes they will be concerned more with the functions of the machines and the effects they are exercising on the fibres than with mechanical details. Fifteen years ago, or even ten years ago, such a course of instruction as is described could only have been narrow, but the amount of investigation done in the last few years on textile materials and processes has been so great that there is now an ordered and constantly increasing body of knowledge which is not only most valuable in itself but can be utilised for the training of men in a scientific habit of mind. These educational developments cannot be expected to come about rapidly, since they cannot proceed more quickly than the growth within the industry of a realisation of the advantages which can result from the proper application to the problems of the methods of modern science. But it appears to me that though these developments may be slow in coming, they are inevitable. I have stressed throughout this paper the importance of the step taken by the textile industries 15 years ago when they decided to undertake co-operative scientific research on a large scale for the general benefit and not for the advantage of only particular firms. That this step would ultimately involve the industries in the close consideration of textile education was seen quite clearly by the promoters of the Textile Research Associations. It is significant that in both the cotton and the woollen and worsted industries the movement towards the organisation of co-operative research began by the establishment of a "Provisional Committee on Research and Education" for their industry: it is also noteworthy that each Textile Research Association took powers in its Memorandum of Association "to aid and encourage the education of persons engaged or likely to be engaged in the said trade or industry."

It is quite natural that the great task of building up an effective organisation for research has, in the case of each branch of the textile industry, tended to obscure the importance of developing textile education *pari passu* with the development of organised research. Everyone is aware of the fact that there has been for 40 or 50 years a system of textile education which has done useful and indeed invaluable service to the industries; everyone is aware, too, that the system of co-operative research has had to be created swiftly. It is therefore easy to understand why the second task should have occupied most of the attention of the industries concerned. It seems, however, that the time is now ripe for a careful review of the system of textile education, a review in which both representatives of industry and of education take part. Fortunately, there is already in existence machinery for this purpose. The Wool Industries Research Association has an Education Committee which represents both this branch of the industry and the schools concerned with it; the British Cotton Industry Research Association has established, in co-operation with the local Education Authorities, a Joint Standing Committee on Education for the Cotton Industry; and for those problems which are common to the whole group of textile industries there is the Textile Institute itself, whose Charter gives it ample powers as regards both research and education.

One of the matters which must engage attention in the future is the training of the teachers on whom the task of devising curricula and syllabuses and giving instruction ultimately rests. I have spoken already of the great value of the work they do and no one who is aware of the facts can fail to be impressed by their energy and the zeal they show not only in revising their syllabuses and methods of instruction, but in improving their own qualifications for their work. But in my opinion the textile teachers in the more important institutions will ultimately be drawn from men with the same educational antecedents as those which I have suggested as appropriate for the most responsible officials in textile factories.

The teacher of textile subjects in a school of major importance will in fact become an important liaison officer between the two related organisations concerned with the gaining of knowledge and the dissemination of knowledge.

There is one other point to which I should like to refer and that is the possibility of the Textile Institute, like other professional Institutions, co-operating in a scheme for the award to suitable students of what are known as "National Certificates." This is not the occasion to go into details of these schemes, but it may be said that they aim broadly at giving some kind of national recognition to the work of students who have attended evening technical schools, have followed suitable courses of instruction, and have passed specified examinations in subjects in which the professional institutions are interested. The arrangements in each case are framed so as to combine considerable freedom for the school with the securing and maintaining of national standards of attainment.

No such scheme of national certification for students engaged in the textile industries has yet been initiated, and it may be that the time is not yet ripe for it. The Textile Institute has, I understand, had the matter under consideration and will probably inquire more fully in order to ascertain whether a scheme for the award of National Certificates is likely to be both practicable and useful to the industry.

Finally, on reflecting on what I have said in this paper, it seems to me that I may appear to be rather pessimistic about textile education. I should be sorry to be regarded as a pessimist about anything, but I should be still more sorry to minimise the difficulties of the educational problems which face this great industry, in whose welfare we are all so closely interested. For more than a century the textile industry of Great Britain has been predominant in the world. The men who founded it and brought it to its high position were undoubtedly confronted by difficulties quite as great as those I have described and surmounted

them successfully. It is this fact which appears to me to justify not a weary pessimism, but an energetic and enlightened optimism.

The Chairman, referring to the universities' connection with research, said that he thought that it was obvious that just as research in the university required careful consideration, so also should teaching receive careful consideration. He thought they should aim at a qualification of scientific craftsmanship. He expressed the feelings of the audience by saying how much they had enjoyed Mr. Abbott's paper.

PRESENTATION OF "WARNER" MEDALS

The President then made the presentation of the Warner Medal awarded by the Textile Institute for investigations in textile technology to Messrs. J. A. Matthew, M.Sc., A.R.C.S., F.Inst.P., J. B. Speakman, M.Sc., F.I.C., and A. J. Turner, M.A., D.SC. The President said—After those two very interesting and instructive papers, it is fitting that the next item on the programme should be the award of the Warner Medal to three gentlemen for investigations in textile technology. I shall call on Mr. F. P. Slater to introduce to the meeting the gentlemen to whom I have to make these awards.

The recipients were introduced by Mr. F. P. Slater, M.Sc., M.A., M.C., of the Publications Committee of the Institute, who said—Mr. President, before asking you to present the medals to the chosen recipients, I should like to reiterate the reasons why the Institute has chosen this form of qualification for the award of the Warner Medal. It has been said of the late Sir Frank Warner that he was a man of acute determination who, above all else, strove to carry out his work thoroughly and quickly. In short, he was a craftsman.

I urge that the three chosen recipients are craftsmen, who have brought the craftsmanship of scientific knowledge to bear upon the problems of three great branches of the textile industry—Linen, Wool, and Cotton. In so doing they have advanced the science of textile technology, the new craft to which our Institute gave name. Moreover, they have brought renown to our Institute by selecting its *Journal* as the vehicle for conveying to the textile industry the products of their craft. Thus they stand for what Sir Frank Warner stood, and they strengthen the Textile Institute, for whose existence and prosperity he laboured so effectively.

The award of the Warner Medal has a double significance, in part associated with the name the medal bears and in part associated with the achievement its award connotes. No historian of the Textile Institute, studying its first twenty years will fail to remark the name of Frank Warner on almost every page. A Foundation Member, a member of the first Council, and Chairman of the Council from its first meeting to the Annual Meeting in 1918 when he was made President, Sir Frank Warner (he was knighted in 1917) played a big part in Institute affairs. In 1922 a London Section of the Institute was formed, very largely as a result of his enthusiasm and effort, and of this Section he was the first Chairman. At his death in January 1930, the London Section Committee made a proposition to the Council which received unanimous support, to the effect that some form of memorial should be established to commemorate Sir Frank Warner's association with the Textile Institute. It was finally decided that this memorial should take the form of a "Warner" Medal. This medal was to be awarded for published investigations in textile technology which had appeared in the *Journal* of the Institute. Such award to be made in periods of from two to five years. The Council has decided on the recommendation of its Publications Committee that the first awards shall be as follows—

Messrs. J. A. Matthew (Linen Industry Research Association); J. B. Speakman (Textile Department, Leeds University); and A. J. Turner (Head, until recently, of the Technological Laboratory of the Indian Central Cotton Committee).

John Alexander Matthew was educated at Latymer Upper School, London, and at the Royal College of Science, where he obtained an Associateship of the

College and the Physics Prize. He later graduated, securing honours in physics, from London University, subsequently obtaining his Master's degree. His first appointment was an assistantship in the Research Department at Woolwich Arsenal, and while there he became a Fellow of the Physical Society. In 1920 he was appointed physicist in the Research Department of the York Street Flax Spinning Co., of Belfast; while there he became a Fellow of the Institute of Physics. Since May 1927, he has been Senior Physicist at the Linen Industry Research Association at Lambeg. Here he has carried out research work in the measurement of the physical properties of flax fibres, yarn, threads, and fabrics, and in the application of physical measurements to the investigation of technical processes of flax preparing, spinning, and weaving. His publications, which have all appeared in the *Journal of the Textile Institute*, have dealt with the above researches and have included descriptions of special machines devised by him for testing fibres, yarns, and fabrics.

John Bamber Speakman was John Buckley Scholar and Mercer Graduate Scholar of Manchester University, where he graduated in Chemistry, taking honours in the subject. He then conducted post-graduate research under Dr. W. J. Jones, securing his Master's degree for a thesis on "Some Physical Properties of Aqueous Solutions of certain Pyridine Bases." His first appointment was as research assistant to Dr. R. Whytlaw-Gray at Eton College, Windsor. Here he carried out work on the "Properties of Disperse Systems in Air and other Gases" for the Chemical Welfare Committee of the War Office. In 1924 he was appointed lecturer in textile chemistry at Leeds University and was elected a Fellow of the Institute of Chemistry in 1930. His published work which has appeared in the *Proceedings of the Royal Society*, the *Transactions of the Faraday Society*, and in the *Journal of the Textile Institute*, has covered a wide field, but in the main has been based on the molecular structure of the wool fibre. During the war he saw service as an observer in the Royal Air Force.

Arhur James Turner was educated at Wilson's Grammar School, Camberwell, and Gonville and Caius College, Cambridge. In 1912, he was appointed assistant at the National Physical Laboratory, from which post he became head of the Royal Aircraft Experimental Fabrics Laboratory To Manchester University and College of Technology he proceeded as Professor of Textile Technology in 1919, which post he held until appointed Director of the Technological Research Laboratory of the Indian Central Cotton Committee, Bombay. His publications cover technological reports on Standard Indian Cottons and numerous scientific and technical papers on textile subjects published by the Indian Central Cotton Committee, the Advisory Committee for Aeronautics, the *Journal of the Textile Institute*, and various textile and agricultural journals. He is now on the staff of the Shirley Institute, Didsbury.

The ceremony of presenting "Warner" Medals was followed by luncheon, which was served in the ballroom adjoining the lecture-room to about 150 members and ladies.

THE INSTITUTE MEDAL

After the luncheon, medals were presented by the President, in appreciation and recognition of services to the textile industry, and in particular to the Textile Institute, from 1910 onwards, to Messrs. A. F. Barker, M.Sc., F.T.I. (Leeds); W. T. Boothman, F.T.I. (Bolton); F. Bradbury, F.T.I. (Belfast); H. P. Greg, M.A., F.T.I. (Manchester), F. Nasmith, F.T.I. (Manchester); and H. Nisbet, F.T.I. (Manchester).

In January 1917, the Chairman of the Council, Sir Frank Warner, "raised the question of the position of the Institute in relation to various research movements, and suggested that steps be taken with a view to substantial increase of Institute membership." It is no exaggeration to say that from this apparently humble suggestion the main developments in Institute functions have arisen. The first

step was a meeting of Presidents and Past-Presidents from which was launched the Institute Development Scheme, and its Foundation Fund. "The Fund" and "The Scheme" both made a strong appeal to the then President—Sir William Mather—who devoted his presidential energies to these objects, and who marked his association with the Institute by a donation of £1,000 to the Foundation Fund. It was in June 1918, that the award of an Institute Medal appeared as an item of the Development Scheme, and it was finally decided to make such an award for services to the textile industry, particularly through the medium of the Textile Institute. The first medal was awarded to Mr. J. H. Lester, who was a graduate in Chemistry of Owens College, and later manager of the Manchester Chamber of Commerce Testing House. He was one of the founders of the Textile Institute, which he has served as member of Council, Chairman of the Publications Committee, Chairman of the Selection Committee (Institute Diplomas), and Vice-President. The award was made in October 1921, by Lord Emmott, who said: "Mr. Lester was, I understand, mainly instrumental in founding this organisation. It has certainly been to Mr. Lester's wide outlook that the breadth of the Institute's constitution has been due." It was not until 1930 that a decision to award further medals was reached, and in this year medals were given to Messrs. John Crompton, William Frost, Frederic R. McConnel, and T. Fletcher Robinson. The awards made on the occasion of the Institute's Coming-of-Age Celebrations are noteworthy in two respects; each recipient is a Fellow of the Textile Institute; each was a member of the first Council of the Institute; and, with one exception, each has been a member of the Council since.

Aldred Farrer Barker was a foundation member of the Institute. He was first engaged in textile education as Head of the Textile Department, Saltaire Technical School, and then for 21 years Professor of Textile Industries at the Bradford Technical College. Since 1914 he has been Clothworkers' Professor of Textiles in the University of Leeds. He is a member of the Worshipful Company of Weavers of the City of London, and has been admitted to the Freedom of that City. He has served the Institute since its inception, first as Vice-Chairman of the Council and later as Vice-President.

William Thomas Boothman, who is Managing Director of John Kershaw and Co. Ltd., and the Haslam Weaving Co. Ltd., both of Bolton, has for many years been associated with the administrative side of the cotton textile industry. He is Vice-Chairman of the Bolton and District Cotton Manufacturers' Association and a member of the Central Committee of the Cotton Spinners' and Manufacturers' Association. He is a Past-President of the British Association of Managers of Textile Works, and is Chairman of the Lancashire Section of the Textile Institute.

Fred Bradbury has occupied the position of Head of the Department of Textile Industries at the Belfast Municipal College for 26 years, and is Extra-Mural Professor of Queen's University, Belfast. Prior to going to Belfast, he was occupied in a similar capacity at Halifax and Shipley respectively. He is the author of several text-books, including "Carpet Manufacture," "Calculations in Yarns and Fabrics," "Jacquard and Harness Mounting," "Flax Culture and Preparation," and "Worsted Preparing and Spinning."

Henry Philips Greg is a cotton spinner and manufacturer, being Chairman of Ashton Bros. & Co. Ltd., R. Greg & Co. Ltd., and of the British Northrop Loom Co. He is also a Director of the Eccles Spinning and Manufacturing Co. His interest in the scientific and technical side of the cotton industry is shown by the fact that he has been associated with the British Cotton Industry Research Association since its inception, and is now Chairman of its Council. He is a member of the Court of the University of Manchester and Treasurer of the Manchester Whitworth Institute. He is a Vice-President of the Textile Institute.

Frank Nasmith was a student of the Manchester College of Technology Textile Department, and subsequently entered the spinning and weaving mill of Messrs. Charles Gee & Sons, Kearsley. He later joined his father, the late Joseph. Nasmith, who was then Editor of the *Textile Recorder* and a consulting textile engineer. On his father's death in 1904 he succeeded to the editorship, which he retained until 1915, when he joined His Majesty's Forces with a commission in the Royal Engineers, seeing service in Egypt and Palestine. On demobilisation he became managing-editor for the publications of John Heywood Ltd., which post he relinquished in 1927 to join the Universal Winding Co. as Executive Manager for Great Britain. He is a Vice-President of the Institute and Chairman of its Council.

Harry Nisbet was first associated with the textile industries as Jacquard Designer for Messrs. Barlow & Jones Ltd., Bolton. From 1896 to 1917, he was Weaving and Designing Master at the Technical College, Bolton. He is a member of the Advisory Committees of the Union of Lancashire and Cheshire Institutes and of the City and Guilds of London Institute for Courses in Cotton Weaving. He is a member of the Council of the British Association of Managers of Textile Works. He is now in private practice as a textile consultant. He is the author of works dealing with Textile Design, Preliminary Operations of Weaving, Theory of Sizing, and Cotton Cloth Calculations.

The recipients were introduced by Mr. Wm. Howarth, J.P. (Past-President), who said it was usual on an occasion of that sort to refer to the work of the institute or association under which the programme had been arranged, but he thought it would be a waste of time to narrate to that assembly the work in which the Textile Institute was engaged and to give a full survey of what it was doing. They knew it just as well as he did. Notwithstanding that, the particular duty he had to do gave him great pleasure to carry through, and it was necessary that he should say a few things. The first thing he had to say was that they should be grateful to these men who in days gone by thought there was a use for the Textile Institute, and who laid the foundations for the Institute, and built successfully year by year the superstructure which had become better as it grew. He was quite sure they must thank these founders, too, that they had had the vision to attract to the Institute young men. When he looked round the room he found a blending of youth with age which should give them courage to think they were not the backward and effete people that the rest of the world conceived them to be, but that they were to the forefront in thought and practice. An Institute like theirs was a complete answer to the defeatist views of some people in this country to-day. The Institute was not an end in itself; it was founded that there should be built into our textile industries all that is best and most capable, and all that tended to keep us in the forefront of the industrial life of the world. That was the broad outlook which actuated Sir Frank Warner in 1917, when he said that the Institute was not on sufficiently broad lines, and he thought the work could be developed in a broader and more efficient form than it had been up to that time. He gathered round him a band of enthusiasts to carry his ideas into effect until they found that day that the Institute was celebrating its entry into manhood. He was sure that the new President would see to it that the Institute in the first flush of its young manhood would widen its circle of usefulness.

They had also to thank Mr. J. H. Lester, because he was one of those on whom the donkey work of Institute foundation rested, and they knew it was not always those who did the donkey work who were fully recognised. Sometimes the names of some of the hardest workers were unknown to those who benefited by the work. Mr. Lester had been honoured by the Institute in a similar way to those who were being honoured that day. There were many others who had not had the medal but they must content themselves that their names were written in the book of life. The glory of life was in the race they ran and not

in the prizes they picked up. He was sure that the gentlemen who were to receive medals would not consider that their work was done because they had received the prizes. They could if they liked put them in the cupboard and forget them as long as they continued to work for the Textile Institute as they had done in days gone by.

Professor Barker, speaking for all the recipients, said he hardly knew how to express himself because it was an occasion which was greater to him than to anyone else, excepting perhaps to Mr. Lester. He had seen the Institute develop from before it was an Institute; he was associated with Mr. Lester and Mr. Moores before it was formed, and now, as he looked round and saw the status the Institute had attained, recollections of those early days came to his mind. The first meetings in Manchester were not altogether successful, but by persistence they had influenced the cotton, wool, silk, and linen industries with their enthusiasm, and he thought they had fairly well succeeded. He felt more than proud to be a recipient of the medal of the Institute. He felt more than repaid for any work he had done. He would not rest in the future, but go forward to help the Institute in every way. In saying this he was only voicing the feelings of the other recipients.

The President, in conclusion, thanked Mr. Howarth for his excellent speech and for his introduction of each of the recipients. Mr. Howarth had always taken a keen interest in the Institute from its earliest days, and it was pleasant to hear him say such nice things about the workers who had been honoured that day.

In the afternoon, the members were conveyed to the Shirley Institute of the British Cotton Industry Research Association at Didsbury by motor conveyances. On their arrival they were met by the Director (Dr. R. H. Pickard) and the staff, and were conducted round the various departments of the Association's laboratories.

THE "COMING-OF-AGE" BANQUET

There were about 150 members and guests present at the banquet in the evening. The speeches of the principal speakers, The Lord Mayor of Manchester (Alderman George F. Titt), Lord Barnby, and Sir Percy Jackson, were broadcast.

The toast **"The Textile Industries"** was proposed by the Lord Mayor, who said—"Whilst I fully appreciate the honour which the Textile Institute has paid me in inviting me to propose this toast, I confess I am compelled to approach the subject quite definitely as a layman. I feel, however, that it is the duty of the chief citizen of Manchester to pay tribute to the industries which have brought Manchester to her proud position in the world of commerce, and it is in that spirit that I shall ask you to bear with me for a few moments while I focus attention on the textile industries of which Manchester is the most important centre.

"It is said that nine-tenths of the whole population of the world wear cotton in one form or another, but I have no need to emphasise the importance of textiles at this function. You are all well aware of the difficulties with which the textile industries are faced at the present time, and it is a matter of pride that those concerned in Manchester and Lancashire are energetically taking steps to restore trade to Lancashire. The celebration then of the coming-of-age of the Textile Institute comes appropriately at a time when we should be reminded of the value of the educative side of the cotton industry and of the efforts which are made to produce thoroughly qualified experts in textile technology.

"Manchester is, and should be, the main centre of textile education. Besides the Textile Institute, we have our College of Technology, which is a faculty of Manchester University, where a student can go through a mill in miniature so to speak, and the Shirley Institute of the British Cotton Industry Research Association, in which the staff pursues a definite programme of research in collaboration

Coming-of-Age Celebrations

MR. W. SCOTT TAGGART   MR. F. NASMITH

MR. J. W. NASMITH   THE PRESIDENT

Presentation of Certificate of Honorary Fellowship of the Institute to Mr. John W. Nasmith

with practical men in the mills. I am told that this Research Association has been a heavy financial burden on the cotton trade, and that it is costing a large amount annually, but I feel certain that the results will amply justify the outlay.

"The practical men of the industry—the spinners, weavers, bleachers, dyers and finishers, and others, are handicapped by world conditions and are very much disturbed by prospects of drastic reorganisation, rationalisation, and so on. There is a magnificent opportunity now for qualified experts of the industry to rise to the occasion by studying the causes of trade depression and advising how best they can counter them. I am informed that important benefits have resulted by the discovery of additional uses of textile materials. For instance, the electrical industry and the motor car industry are taking textiles in increasing quantities, and only the other day at a ceremony at which I had the honour of welcoming the arrival of the S.S. "Surrey," laden with a cargo of New Zealand produce which she brought direct from the Dominion to Manchester, the High Commissioner for New Zealand reminded us that New Zealand had bought 1¼ million yards of cotton wrapping for use in the covering of meat for shipment.

"When I realise all the skill which is being brought to bear on this problem of the restoration of the cotton trade; I have every hope that other avenues within the trade will open out.

"May I refer to our Prince Ambassador? His Royal Highness the Prince of Wales has by word and deed devoted himself to the question of the importance of our markets abroad. Mainly as a result of his stimulus, organised delegations and trade missions have visited foreign parts with a view to securing direct contact with the world's markets and obtaining first-hand information as to requirements and possibilities. China, Egypt, the United States, and Canada have all recently been visited by delegations from this country, and now the Prince is returning from his business tour in South America. I am sure we all profoundly admire His Royal Highness's keen personal interest in commercial affairs, and are deeply grateful for his devoted efforts in keeping British goods before the world. To-day I had the pleasure of attending a luncheon given by the Lancashire Industrial Development Council, at which Lord Derby was elected President. The objects of the Council are generally to further the development of new industries and the extension of existing industries in the industrial area of Lancashire.

"You may also have heard of the formation of a Manchester Development Committee. I am anxious that it shall soon become an effective unit in the city, actively operating for the benefit of all sections of the trading community, and for that purpose it will co-operate closely with the Lancashire Industrial Development Council, which will cover a much wider area than the city and will deal with industrial questions which are not within the purview of a municipality.

"Last evening the Textile Institute honoured Mr. J. W. Nasmith for his wonderful invention of a comber, and I should like to add my congratulations on behalf of the city that yet another Lancashire man has joined that line of great inventors—Paul, Hargreaves, Arkwright, Crompton, Cartwright, Kay—who have contributed so largely to modern efficiency in the manufacture of cotton.

"It is distinctly reassuring to notice that the different sections of the textile trade—so clear cut hitherto—are becoming more interdependent and more adaptable. I sincerely trust this movement will proceed rapidly and lead to a wider unity within the textile industry as a whole. There are enormous difficulties in the way, but no one can make me believe that the men of Lancashire, whose forefathers have developed the manufacture and merchanting of textiles to their present excellence, cannot find a way out. They will do so, and here is a body, the Textile Institute, which will be a considerable factor in their success. After 21 years of existence, it is pursuing its work with increasing vigour and producing a publicly recognised class of experts in textile technology.

"I wish the Institute every success and with confident expectation of prosperity I have pleasure in proposing the toast, 'The Textile Industries,' coupled with the name of Lord Barnby."

Response by Lord Barnby

In responding to the toast, Lord Barnby said—"Publicity in connection with the events of these three days have brought the Textile Institute much into the public eye. To those present to-night its history and aims are already familiar. By a much wider circle it will be readily grasped that its activities cover a field of thought and action of vital importance to the textile industries, and its scope entitles it to the widest support. That these celebrations should occur in Manchester is appropriate and compatible with the dignity of Manchester's position in the textile industries. The speech which we have just heard from its chief citizen appropriately deals with the importance of the textile industries in the Nation's economy. I shall, therefore, address myself to some of the wider problems, industrial and economic, which occupy responsible minds in the industry. I would, however, first comment on a few relevant figures. The textile industries in 1929, including apparel, contributed 238 million pounds value, or 41% of the country's total manufactured exports of 573 million pounds. The insured workers in all branches of the textile trades, that is cotton, wool, silk, rayon, linen, jute, and clothing, amount to roughly 1,800,000 out of a total of 12,400,000 insured workers in the whole country, so that of those employed outside of domestic service and agriculture, at least one in every seven of the working population is engaged in textiles or succeeding occupations entirely dependent thereon.

"These figures will suffice to give a glimpse of the importance of these industries to the nation. It is, of course, sad that the curve of Lancashire's total exports should have been recently so steeply downward. It should, however, be pointed out that from the point of view of domestic employment the tendency is less disquieting than would appear on the surface. Take for instance two items—cotton and mechanical vehicles. In 1924 cotton goods accounted for not less than 32% of the value of manufactured goods exported, while mechanical vehicles amounted to only 4%, but by 1930 the figures had so changed that cotton accounted for only 20%, while vehicles were over 12 per cent. But naturally, owing to the large proportion of imported raw material, the labour content in the selling price of the cotton goods will be very much lower than the corresponding proportion for vehicles It was inevitable that the former large export of textile machinery combined with the stimulus to national development and the building up of domestic industries in foreign countries, assisted by tariffs, must inevitably react unfavourably on British exports.

"There has recently been published the report on the Cotton Mission to China. This is a momentous document. I was privileged, as a member of the Development Council of the Department of Overseas Trade, to listen to the remarks of Sir Ernest Thompson and Mr. Bell at the meeting when the report was presented. It certainly is an informative document, and all will admit that its courageous conclusions demand new outlook in the textile industries. Indeed, it is generally admittted among the younger elements in the textile industries that there is indeed need for a new and changed outlook; traditions must be ruthlessly scrapped. Too long has technical knowledge been valued above administrative efficiency. Academically-trained brains must replace rule-of-thumb practice. An engineering outlook should govern fibre manipulation. The habit should develop of thinking in percentages instead of quantitatively. We are certainly hampered by our system of weights and measures, but that is no reason why straight pounds should not universally replace cwts., qrs., and lbs.

"These may be relatively insignificant points, but they are discriminating. Again trade practices, specifications for contracts and trade terms need scrutiny.

You in Lancashire have had much contact lately with rationalisation, and the courageously conceived scheme, inspired by the Bank of England, is surely entitled to a fair chance to prove itself by all loyal citizens. Outside this county, whisperings have been heard that vested interests and personal jealousies and animosities have hampered its progress. Such would surely be a reflection on the fair name of this industry. It is past the wit of man to conceive a scheme which will be free from faults, but it ill-becomes interested parties to unfairly exploit its handicaps. There are many who question the hitherto disclosed results of rationalisation in other industries and other countries; I am among those who definitely believe in it, but in the textile industry I believe in small physical units as against large physical units, but as complementary to this, in industries horizontally constructed, such as the British cotton and wool industries, a chain of units under Central Financial Control. It is surely the large number of individual units in the textile industry which makes so much more difficult the dominating problem of the moment—that of adjusting production to demand, and also, what is of equal importance, proper publicity and representation in foreign markets. Extreme individualism built up the textile industries, but as modern transport demanded the substitution of steel ships for wooden ships, it seems open to question if modern economy does not call for the gradual passage from individualism to disciplined co-operation.

"The recent report of the Joint Committee of Cotton Trade Organisations courageously suggested the introduction of statutory powers. There are many who feel that without this real progress cannot be made. For some purposes, such as the collection of data, essential for measuring the problems of the industry or the equitable assessment of funds for research purposes, it is hard to discern an effective alternative.

"In cotton, you import most of your raw material from without the Empire. In the sister industry of wool textiles, the bulk of our supply comes from within the Empire. Wool is the greatest of Imperial links. We feel our prospects are rightly more promising than yours, for blending and styling justify manipulation in England. At the moment raw material supplies differ inasmuch as in wool there is no unusual accumulation. Indeed, the figures of wool in store in Australia of only 180,000 bales at the end of March this year, as against 701,000 bales at same date last year, and a carry-over of only 140,000 bales last year, prove conclusively in how relatively strong a position wool is, by comparison with most other commodities, particularly when the average price is still only about 60% of 1914, as against the average of 100% for all commodities.

"Already in wool products there are signs that exhaustion of stocks and current low raw material values are causing an expanding market, and let us hope that this will shortly extend to other textile industries.

"Returning to the report of the Cotton Mission to China, to which I have already referred, the outstanding feature is the indictment of the existing individualistic system. Frequently when costs are mentioned, costs other than production, particularly other than those of marketing, are referred to. Admittedly, in the textile industries, a recovery of foreign markets demands sacrifices, including a revision of trade union practices. Fortunately we may assume that the traditional and rigid outlook in the labour ranks is mellowing, but it is right they should look for equal sacrifices all round, and an encroachment on individualism which alone would permit the cutting down of costs supplementary to manufacture, and afford real combined power in marketing. The old established media, either through lack of enterprise or exhaustion of resources, do not seem sufficient to develop new foreign trade, but it will expand and it is for that moment that our reconciliation is required, and it is natural that the workers if asked now to make sacrifices should feel confident that matters outside their control are also being thoroughly recast.

"Fortunately this country has a splendid goodwill. The reputation of our products still carries weight, and we have a prestige which combined with our traditional skill can assist our traders. We know that 'out of sight' is 'out of mind'; that must be avoided at all costs; we must make a greater stir in those valuable overseas markets.

"Remember! in the end, the tendency of the stream must inevitably be towards the subordination of political connections to economic interest, and I believe this to be true, not only in regard to our national life, but also in the relation between nations. Diplomacy as such, and in the terms of pre-war definitions, has definitely lost ground; the structure and activities of embassies and legations have taken a new direction; commercial councillors and trade commissioners play the important part in diplomacy to-day. Trade missions are multiplying, and everyone of us must welcome the enterprising spirit being shown by this country in that direction.

"The inclination of the man in the street is to ask himself, 'Where do we cash in—as an individual, as a family, as a town, or as a nation ?' This force is cumulative and it would seem irresistible; we are coming to think in new terms and with new objectives, and what is perhaps an unconscious movement towards the subordination of political connections to economic interests will rapidly crystallise into a conscious effort, resulting in an adjustment of political parties, political connections, and possibly the scope of Parliament itself.

"In conclusion I would repeat that while the trade cycle during a period of a declining price level has been so obviously against this country, I hold that at the commencement of the upward curve of improved trade, our traditional experience, our accumulated wealth, and in the case of Lancashire our operatives and our plants, will all contribute to regaining a large part of the world's trade. Let us not be afraid to boost ourselves—let the world know about us; our intentions, our products and their intrinsic value, and let us go to it with confidence and determination to beat the world."

The toast of **"The Textile Institute"** was proposed by Sir Percy Jackson, who said that anyone thinking about the history of the Textile Institute recognised at once that during the last 21 years the Institute had had among its members the very foremost people in the textile industry in Lancashire and Yorkshire. He could not forget that in 1925 Mr. John Emsley was the President when they were granted the Royal Charter, which opened up for them a far greater sphere of work and usefulness than had been possible previously. The powers conferred on the Institute by its Charter in doing examination work and conferring diplomas had indeed opened out a new sphere of work which would take them very far indeed. They had at this time probably a greater need for people who were enthusiastic in their work, apart from people who only did an ordinary day's work, from the standpoint of science, art, and invention. They had a greater need for those people than ever in the past. If Great Britain was to retain its place in the great textile world of the future, it would be by science, art, and invention; by the greater use of art along with invention and science because he thought that in the past they had laid too much stress upon science and invention and not enough upon art.

To-day they were all talking about costs of production, cost of social services, cost of wages, but he did not want them to hang their harps upon that particular willow tree. He thought that would make them lose heart. There were other things besides costs of production, and the Textile Institute stood for those other things. They knew that the cost of social work was about £15 per head of the population in this country, the cost in France was £10, and in Italy something like £5. If that alone ruled prosperity, while we ought to be well out of the running, France ought to be doing better, and Italy ought to be the top dog. As a matter of fact, Italy was the worst hit of any of them at the present time, and France, coming next in the cost of social services, had, he thought, been

the most prosperous nation in Europe as far as textiles were concerned during the last ten years.

The Textile Institute had done extremely valuable service in bringing technical work to the notice of our young men. During the past two years he had been Chairman of the Yorkshire Council for Further Education. That Council, which was acknowledged by the Board of Education, had set itself the task of bringing together youths of all trades, the best men in the trades, together with teachers and demonstrators, and local authorities. They had succeeded in bringing these people together and also had made such arrangements for supervision that the boy entering the evening school was cared for until he finished his training at the local technical school.

He read the other day in *The Times* an article regarding M. Siegfried's book, "England's Crisis," and he determined when he received the Institute's invitation that he would have something to say about it. In his view that book was unfair and a travesty of the manufacturers and producers in this country. As he read it he repeatedly said, "I know where he got that," and it seemed to him that Siegfried had gathered together all those sayings in which we had depreciated ourselves and put them into his book. One of the most unfair things he said was that the manufacturers in this country did not know their job as well as French manufacturers knew theirs. He had been on business in Paris, and while he did not depreciate in any way French buyers and manufacturers, he said deliberately that they did not know their job any better than our manufacturers knew theirs. The bulk of business in this country was not carried on by a few huge firms; the great business of this country was carried on by the moderate firms, and those firms were in the hands of one, two, or three men who put all their energy and initiative and individuality into their work. Even if trade wanted reorganisation there was still room for individuality in this country as far as industry was concerned. He was sure that the young men of business to-day were better men than the older men; they were more energetic; they had more science and were better educated, and they would do better eventually. The Textile Institute was a voluntary organisation, and there was a great place in England for voluntary effort of that sort. The missionary work was done. Eventually the Government of the country must take over a great deal of the work, and they would be able to show the Government the steps they should take as far as the textile industries were concerned.

Responses by the President, Mr. Lester, and Mr. Garnett

The President, responding, said a lot had been said about the Textile Institute during the 21 years of its life, and there was no need to repeat any of it, but he would say that on its 21st birthday they had to look forward to the future with a desire to extend and to grow. They were honoured that night by the presence of Lord Derby, who as everyone knew had done an enormous amount for Lancashire and its textile industry. If they had been inclined to sleep on a problem, Lord Derby had always given them the necessary push to start them off again. They knew that he had the textile industry and particularly the Lancashire textile industry, absolutely at heart. The Textile Institute embraced every branch of the textile industry in every part of the world. That was all right as far as it went. It was a great mistake to feel confident that they were unapproachable in textile organisation and production. As previous speakers had pointed out, they were finding that every country was learning from them so rapidly that they were producing goods for themselves, and producing if not as good products, at any rate very good substitutes. They had all seen various markets lost, and the textile machinists had discovered they were not the only people who could make textile machinery, but that other countries where textiles were manufactured were starting to make their own machinery. Through Textile Institute membership, they could exchange knowledge from international sources, and that was one of the things the Textile Institute was doing

through its *Journal* and its meetings. Wherever their meetings were held they ought to have one object in front of them, and that was to extend the influence of the Institute as far as they could. It was essential that they should increase the membership, and anyone who had their trade at heart should become members and share the benefits the Institute offered. If everyone would put their back into the work the Textile Institute would soon occupy its proper place as a scientific organisation.

Mr. J. H. Lester, M.Sc., replied on behalf of "the little band who 21 years ago had the temerity to establish the Textile Institute." He was glad to see present Mr. George Moores who, along with himself, was active in the beginnings of the Institute, and who for some years acted as Secretary. The first meeting was extraordinarily representative of the textile industry of that day, and not only were these representatives from the industry, but the support given by others who did not attend was really considerable. There were present at the meeting Professor Barker, who was there that day, Professor Fox, Mr. W. P. Crankshaw, Mr. H. P. Greg, Mr. Oscar Hall, Mr. Hubner, Mr. P. T. Johnstone, Mr. Knecht, Mr. Cedric Lee, Mr. E. Marsden, Mr. Nasmith, Mr. Nisbet, and Mr. J. O. Potter. They had letters from Sir Thomas Coates, Sir Wm. Holland, Sir H. F. Hibbert, Sir Wm. Mather, Sir M. Oldroyd, Messrs. E. Armitage, Robert Beaumont, F. H. Bowman, F. Bradbury, S. J. Chapman, F. Debenham, W. Henderson, Harold Lee, K. Parkes, F. Warner, W. Watson, and T. Woodhouse. What they did at that time was inevitable. Societies existed for various industries in this country, and to a great extent they had patterns to go on from those societies. In the main he would say that the Textile Institute was established to bring together the art and science of the textile industry. The industry, to-day, consisted of a number of separate units badly correlated to one another. They had the spinner, very frequently an excellent man thoroughly acquainted with his job but knowing nothing of weaving, and the finisher who knew nothing of the manufacturing of the fabric and little of the merchant. One of the chief objects was to bring together these various units and make them a vertical combine. By their Charter they had obtained authority to set up examinations with the object very largely of bringing together these various interests. It was the intention to qualify only those who, while specialists in one particular branch, had a reasonable grounding not only of one branch of the textile industry but of all of them. They would like to see the membership increase, but they would only get the increase they deserved. They had means of doing that, namely, by the quality of the papers read before the Institute, and by the increase in the number and quality of those appearing in the *Journal*. He regarded the *Journal* as the mainstay of the Institute. Unless that flourished he could scarcely see the Institute making the progress it should. There were many things still to be done. There were aspects of education in which the Institute had so far taken little interest. There was, of course, the question of how far the youth of Lancashire were being trained as they should be. There were many other questions in education; for example, as to whether the matriculation examination as it at present existed was adequate, and were there artificial barriers, such as prejudices, to be removed. We might have to consider these things in the future and it was largely for the Textile Institute to consider what could be done to bridge the gap which existed between the man in the school and the man in the industry. This was a matter in which they could be of great assistance to the employers. Speaking of employers, he wished to say how grateful he was to his own employers, Messrs. Tootal Broadhurst Lee & Co., who had given him time to devote some of his energies to the Textile Institute, and he hoped that example would become more generally copied.

Mr. George Garnett (the President-elect) said that when he attended the inaugural gathering 21 years ago he never dreamt he would be invited to occupy the presidential chair 21 years later. He started his association with textile

societies at 18 years of age, and he had always been associated with them from that time to the present. It was indeed a proud moment to feel that one was associated with an Institute with such ambitions as they rightly had that day. Their fathers had laid the foundation so that the present generation was able to take a much wider outlook, and the Textile Institute provided the link between such places as Shirley and Torridon and the textile industry.

"Our Guests" was proposed by Dr. R. H. Pickard, F.R.S., and was responded to by Mr. B. Mouat Jones, D.S.O., M.A.

MEETINGS AND VISITS ON FRIDAY, 24th APRIL

Friday's session of the celebrations was presided over by Mr. F. W. Barwick. Two lectures were delivered, the first by Dr. W. H. Gibson, O.B.E., B.Sc. (Econ.), F.T.I., Director, Linen Industry Research Association, and the second by Dr. S. G. Barker, F.T.I., Director of Research, Wool Industries Research Association.

The Chairman said that he need hardly remind that audience of the close relations between the four textile Research Associations and the Textile Institute. The Directors of those Associations were members of important committees of the Institute and took a close interest in the work. They had had the privilege of visiting the Shirley Institute, and it was very fitting that morning that they should have the pleasure of listening to lectures by the directors of two other of the Research Associations. It was a particular pleasure to welcome Dr. Gibson and Dr. Barker. As head of the Linen Research Association, Dr. Gibson was well known to them either personally or through his public work, and it was therefore hardly necessary for him to remind them of the work he had done for textile research in the linen industry.

FLAX FROM FIBRE TO FABRIC

By W. H. Gibson, O.B.E., D.Sc.
(Director, Linen Industry Research Association)

On such an occasion as this, when we are celebrating the coming-of-age of an institute which has had a great educative effect upon the textile industries, it seems to me that a lecture showing the general trend of development in the linen industry during the past 21 years might be more appropriate than a highly technical discourse upon one selected subject.

For this reason, I have chosen a general title and I am able to draw upon the vast amount of information made available in the *Journal of the Textile Institute*.

In pre-war days when the Textile Institute was founded, our textile industries were pursuing the even tenor of their way and it was only an enlightened few, among whom I am glad to say that leaders of the linen industry were well represented, who saw any necessity for further scientific and technical education, information, and research in the textile industries. The subsequent course of events in industrial history has demonstrated to the full the foresight of your founders and it is not too much to say that the existence of the Textile Institute has provided a rallying-point for all friends of scientific progress in the textile industries. The same people who supported the Textile Institute we find, as occasion offers, supporting the co-operative Research Associations and other movements towards industrial efficiency. Turning to the particular case of the linen industry before the war, we find that it occupied a very favourable position. It possessed assured supplies of raw material of all grades, its manufacturing operations were carried on by a personnel having unequalled technical skill, and its products enjoyed deservedly a wide and constant market.

The tendency to rest content with such a satisfactory state of affairs was, of course, very strong, but the violent disturbances of trade due to the war and its after-effects have shown up clearly the dangers of inaction. Over the period with

which we are concerned we find that change, often scarcely noticed at the time, has been the order of the day and that much of that change has been due to the systematic application of science to the industry.

With reference to the raw material, flax fibre and its production from the flax plant, the linen industry has been given the riddle of Soviet Russia to solve, and it can hardly be said that the solution of this problem is definitely ascertainable.

Before the war the Russian peasant grew an immense acreage of flax, almost 3½ million acres, producing about half a million tons of fibre. About 50% of this was exported to Western Europe at a cost of £30 per ton and the rest was used by the Russian peasants and by the growing Russian linen industry. The import of flax from Russia into the United Kingdom reached 80,000 tons, leaving about 25,000 tons imported from Belgium and other countries, and an Irish production of 12,500 tons.

The yield per acre of Russian flax was only about 360 lb. of total fibre, while Irish flax yielded 600 lb. and Belgian about 1,000 lb. The price of the different classes of flax also were in the same order, Russian averaging £30 per ton, Irish £50 per ton, and Belgian £70 per ton. Russia thus supplied the bulk and the lower grade of flax fibre and determined the supply and the cost of the raw material for the linen industry. The supply of Russian flax was interrupted by the war and the revolution in Russia which led to a great increase in the acreage of flax in Ireland but the yield per acre fell, probably owing to a distinct lowering of skill in handling and quality of product. It is now doubtful whether Russia can be relied upon as an unfailing source of supply of flax for Western Europe. It would seem that the yield of flax there is possibly 40% less than before the war, and that if the Russian peasants and the Russian mills absorb their normal quota, a surplus for export is unlikely. However, under present conditions a surplus for export can be secured by action on the part of the Soviet authorities in limiting the home consumption.

The Baltic States formerly included in the Eastern Empires continue to grow about 700,000 acres of flax as they did before the war and their yield of fibre has not fallen as in the case of the Soviet, giving 400 lb. to the acre Of the 120,000 tons of flax produced annually only about 35,000 tons reaches the Western market. Belgium and France have maintained their acreage of high-quality flax and their production is near the pre-war figure.

This situation has caused the British linen industry to turn its attention more closely to the production of high-quality goods. The flax imports show that the supplies of flax secured from Belgium are practically the same as before the war, but only about 25% of the quantity imported from Eastern Europe before the war is now taken. This is shown in the following table—

Imports of Flax

	Quantity 1913 tons	1929 tons	1930 tons
Russia	68,181	1,894	1,557
Esthonia	--	2,494	1,463
Latvia	-	11,169	13,689
Netherlands	1,442	2,369	1,293
Belgium	14,194	15,585	12,942
Other Countries	473	2,947	1,524
Total	84,270	36,458	32,468

In view of the raw material position, it is not surprising that upon the formation of the Linen Industry Research Association in 1919, it had for its most important problem the botanical study of the flax plant. The object of this work was to increase the yield of fibre per acre and also improve the quality of the fibre grown so that the area of supply of good to medium quality fibre might be extended and

the upward trend of the linen industry in quality, partly caused by the diminution of low grade Eastern European supplies, rendered easier. This has led to a study of the heritable qualities of the flax plant and patient selection and plant breeding work over a long period of years to accumulate a number of pedigree strains of flax possessing desirable characteristics for yield and quality.

It was, I think, at one time hoped that the provision of these pedigree strains of flax to Irish and other farmers would, of itself, increase the yield and quality of the farmer's crop of flax to a greater degree than has proved to be the case. However, it was shown from the returns made during the years 1926 and 1927 by farmers growing J.W.S. pedigree seed, the first of the new varieties to reach commercial bulk, that their average yield was very nearly 50% greater than the average yield in Northern Ireland for the same years. This agreed with the percentage increase shown in experimental trials, but the actual average yield of 600 lb. of scutched fibre per acre, or, allowing for tow, 900 lb. of total fibre, was brought down by too many poor yields due to poor handling of the crop in cultivation, retting, and scutching. It was also apparent that the quality of the crops grown by the farmers from the pedigree seed had not surpassed that grown from ordinary seed as it should have done on account of the greater regularity and uniformity obtainable from a pure strain. The original J.W.S. strain was selected solely upon the external characteristics of the plant, of which height is the most important in relation to the yield of fibre, but all succeeding strains introduced by the Linen Industry Research Association, known as Liral strains, have been selected principally for internal characters, of which the actual fibre content of the stem has the most bearing upon yield of fibre.

In all the plant breeding work new strains have been originated from a single parent plant, bagged from the day of first flowering to prevent cross-pollination, and the succeeding generations are examined for trueness to type. The judgment of a flax plant by its actual fibre content has involved the development of a systematised technique for cutting practically perfect sections in large numbers. The cross-section is taken midway between the cotyledons and the first flowering branch and the plant is pulled and prepared for this purpose exactly 35 days after the first flower appears. After pickling, the stems are embedded in celloidin and the sections are cut with a large pattern flat cutting microtome. The sections are double stained to show up the ring of fibre bundles, and are examined under the microscope using a projection apparatus, which permits of the measurement of the total area of the cross-section and the area of the fibre bundles. The strains which consistently show a high percentage of area occupied by fibre bundles over several generations are chosen for further propagation. The quality of the fibre in the stem can also be judged to a considerable extent by the disposition of the individual fibres composing the bundles and by the thickness of the fibre wall compared with the central cavity. Fibre cells having thin walls and large cavities are coarse and of poor quality.

It should be mentioned that from the point of view of the flax spinner, two distinct qualities of flax are desired, a fine, silky, weft flax and a bold, strong, warp flax. It is one of the problems of the Research Association to produce pedigree strains, which, when grown and handled for fibre extraction, under the best conditions, will satisfy these two needs. This has been solved up to a point by the method of trial and error, although the correlation of fibre arrangement in the stem with the warp or weft nature of the flax has not yet been established. There are, of course, a great number of disturbing factors which arise during cultivation and fibre extraction. Nevertheless, Liral 6 has been found to give consistently a fibre of high quality of a pronounced weft type, but unfortunately it is not one of the highest yielding flaxes. In the same way, Liral 4 is pre-eminent as the highest type of warp flax yet attained. This flax is also one which gives a very high yield per acre and a good seed yield. For this reason, it has been chosen to be grown upon the Royal estate at Sandringham as an experiment to determine

the effect of the characteristic climatic and soil conditions of that district on a flax of warp quality.

This brings me to the next consideration.

Even when a pedigree strain is chosen, and good standard practice is employed in cultivation, the effect of climate and soil upon the resultant flax fibre is very considerable. For this reason, information is being slowly acquired upon the behaviour of all pedigree varieties, which we possess, in different districts and upon different soils.

I think we are moving towards the establishment of two distinct types of flax, a warp and a weft type, adapted to the soil and climatic conditions of each flax-growing area.

Another line of advance which has already been entered upon is that of the establishment of a dual purpose flax, by crossing the linseed and the fibre types of flax. Liral 7 is the first of such flaxes to be produced by the Research Association. Under suitable conditions of cultivation it can provide a large quantity of seed, which can be used for sowing, feeding, or oil production and a good yield of fair to medium quality flax fibre. In the case of a typical linseed growing country such as the Argentine, with an acreage of over five millions and a yield of 600-700 lb. of seed per acre, the use of such a dual purpose seed with very slight modifications in cultivation should be able to maintain the yield of seed per acre and to provide in addition an equal quantity of fibre at little additional cost.

It has already been established that the linseed oil obtained from flax gathered at the stage of ripeness suitable for fibre production is, if anything, superior to the oil expressed from fully ripened seeds. The fibre would have to be extracted from a dual purpose flax by mass production methods very different from those employed for the extraction of high grade fibre. Many attempts have been made during the last 20 years to establish such methods and sufficient success has been secured to warrant the hope that the problem is capable of solution. The attempts which have been made to use ordinary linseed flax, unsuitably grown, were doomed to failure from the start, but this is not the case with a true dual purpose flax.

In addition to safeguarding our flax supplies, the botanical study of the flax plant is having a considerable influence upon the methods of fibre extraction and fibre preparation prior to spinning. A monumental piece of work, carried out at Lambeg, was the reproduction by means of a photo-micrograph, 60 feet long and 9 inches wide, the magnification being 30 diameters, of the complete fibre system of the flax plant.

A study of this photo-micrograph affords convincing proof that the fibre bundles, of which there are approximately 30, run in parallel bands throughout the length of the stem in better alignment for spinning than they are at the end of our imperfect processes for fibre extraction. It is also seen that where a leaf is formed, one of the fibre bundles ends, but the bundles on either side run together above the leaf trace, forming a double bundle which higher up the stem divides into three parts thus maintaining a constant number of bundles throughout the stem. Under existing methods of hackling the formation of a certain proportion of tow, when combing the fibre in the direction from middle to root end, is inevitable and is due to the openings presented at the leaf traces. The bacteriological process of retting has been very much studied, but from an economic standpoint many of the more elaborate methods of carrying on the retting process seem open to question. It seems more and more probable that the simple natural process of retting by steeping in water with suitable control of temperature and flow of water will give a satisfactory result at a cheaper cost than chemical retting or other proposals. Here again, study of the structure of the plant shows that while the action of the bacteria in dissolving away the soft bast cells in which the fibre bundles are embedded loosens them from the inner woody core on the one side, from each other, and from the outer skin of the plant on the

other side, the process is not ideal since the outer skin tissues are left in a gummy state and on drying the stems after retting the outer skin adheres firmly to the adjacent fibre bundles.

As a result of this, fragments of unwanted epidermal tissue are carried right through the spinning and weaving process and have to be broken up and decolourised by the bleacher. Alternative processes, such as mechanical extraction of the fibre without retting, followed by cleaning with detergent liquids, while perfectly successful in the laboratory, have not won success on the manufacturing scale.

One of the most serious problems with retting is not the retting itself but the subsequent drying of the retted straw, and this is so on account of the cost of drying and also because of the harmful effect of uncontrolled drying conditions upon the quality of the fibre.

Natural drying of the flax straw is up to the present still regarded as the most satisfactory procedure. Following retting, the flax straw is broken into short lengths by passage through fluted rollers and these short lengths of wood are knocked out by rapidly rotating blades in the process of scutching. Research has shown that a good deal of disarrangement and damage of the fibre strands can be traced to the breaking of the woody stem into short lengths which are subsequently forced through the surrounding fibre strands, but up to the present no alternative to breaking has been introduced.

The trend of invention in Belgium has been away from the simple Belgian wheel of rotating blades, towards continuous turbine scutching machines, in which the flax straw is fed in at one end gripped by a travelling band, reversed in the middle to scutch the other end and delivered scutched at the end. Such machines increase the output enormously and cheapen the process, but do nothing to obviate the damage caused by breaking the straws. The loss by the imperfection of the breaking and scutching process is a serious one, amounting to about 10% of fibre in this operation itself and causing increased tow production in the hackling process used in the spinning mill to the extent of 25 per cent. On account of this unsatisfactory situation the linen industry has decided that the processes of fibre production must be investigated experimentally on the full manufacturing scale and with the help of a grant from the Empire Marketing Board and the Government of Northern Ireland a flax factory is being erected and put into operation, where full mechanisation of the processes will be attempted and all possible alternative methods of fibre extraction will be tried upon a commercial basis.

The first important process in the spinning mill is hackling or combing the fibre by moving sheets of graduated pins. This operation cleans and to some extent splits the fibre bundles into finer strands. Any matting or tangling in the fibre of course means that good fibre is converted unnecessarily into tow, as the pins will catch in the tangle and break off the fibre. Each piece of flax in passing through the hackling machine is gripped in the middle by a holder, the root end is combed first and then, after pulling through the portion under the clamp, the top end is combed. Much work has been done to determine the causes of loss which depend upon the arrangement of the fibre strands and the position of the clamp as well as the direction of combing and the extent of tangling. The hackling process is followed by sorting or grading of the fibre and it is then put into the form of a sliver or continuous ribbon. This is followed by drawing and doubling over a succession of frames, the fibre being broken down into finer strands by the action of pins at the same time.

The extent and importance of this "break down" has been demonstrated by much experimental work with the fibre strand sorting machine, which was designed to sort the fibre strands in any sliver mechanically into groups of equal length. These groups can then be investigated further by several methods for fineness, upon which the count of yarn which can be spun is dependent. The "breakdown" depends upon two factors, the spinning quality of the flax and the details of the preparing system, so these measurements can be used for the study

of either the material or the process. With known flax of pedigree strain, known methods of cultivation, and known methods of fibre production, it serves as a quantitative method of evaluating the effect of these variables.

The processes of dry or wet spinning consist of a further drawing of the rove between rollers either without or with immersion in water, followed by the insertion of twist by a flyer, which also winds the yarn on a bobbin. Investigation of this process has followed the line of studying the component operations in succession and also of putting yarn spun under controlled conditions through a comprehensive series of tests. Many of the tests are standard methods, others such as the elasticity, wear, and repeated impact tests have been developed by the Research Association. The properties required in a yarn depend on the purpose for which it is intended so that research work becomes more complex and diffused when the weaving process is reached, the problems of the industry resemble those of the other textile industries and investigations are furthered to a still greater extent by the development of discriminative tests of yarns and fabrics.

The dressing of flax warp yarns is usually done with starch mixtures in which sago is frequently used; it is open to doubt, however, whether starch dressings are capable of giving the ideal protective coating for warps and the present tendency to replace starch to some extent by other colloids appears likely to develop. At the Research Institute trials on a small scale can be made upon an experimental sizing machine before larger trials are made in weaving factories. The bleaching process for linen consists in principle of the removal of non-resistant cellulosic material by alkaline treatments and decolourisation of residual colouring matter by hypochlorite or in some cases by grass bleaching. The scientific control of these processes by a number of simple yet very effective tests is now general. The vital importance of the reaction of the "chemick" is fully realised and in consequence the time taken in bleaching has been greatly shortened and at the same time the damage by over-bleaching reduced to very small proportions.

The finishing processes beetling, calendering, mangling, and so on, are now well controlled by appropriate physical tests for thickness, stiffness, lustre, and transparency. Much attention has been paid to the penetration of the vat dyestuffs on linen as these are almost exclusively used. Dress linens are now produced in which practically perfect penetration is secured. In some respects the investigations which are being made upon the physical properties of finished linen fabrics are of more importance than any others.

The properties which differentiate the flax fibre, yarn, and fabric from other textile fibres, yarns, and fabrics, have been for a number of years the subject of careful measurement, and the effect of finishing processes and cloth structure upon these properties is continuously being studied. Work of this kind has led to reliable methods of distinguishing flax from hemp and other fibres and for differentiating between flax fabrics made of high grade (line) and low grade (tow) yarns. It has also been possible, in many cases, by modifying cloth construction or finishing process or both, to enhance in a fabric the particular characteristics desired by the customer in that fabric; such a property as absorbency, for instance, can be varied over a wide range, and in this way the utility and attraction of linen goods for particular purposes have been increased. While there are a number of articles for which linen is preferred upon purely utilitarian grounds, for many there is a large element of æsthetic or sensory appeal, which is only capable of influencing people whose standard of living is above subsistence level and who have been educated to a degree of culture. In spite of the adverse conditions through which we are passing, it is evident that the number of people capable of appreciating and desiring linen is bound to increase with the advance in the general standard of living and education among the peoples of the Western World.

The linen industry can therefore look forward to better times when the present depression lifts and there are potentialities of great expansion in its markets should some few of the possible developments in the way of raw material supplies and new processes of manufacture materialise.

The Chairman said he was sure he would re-echo the feelings of the audience in saying how interested they had been in listening to Dr. Gibson's paper. He had described the many complex problems in connection with linen research—not only biological and chemical questions, but complex problems which were due to the disturbance of the sources of supply

The British Empire took second place to no other country in the world in the number and eminence of research workers on the wool side, and Dr. Barker occupied a very prominent place in a distinguished company of British research workers. He felt sure they would be familiar with his published work; he was a prolific writer and his work covered all phases of the industry from wool production to standardising methods of testing the fastness of dyes for the finished product. They would no doubt be familiar with that excellent publication of his about two years ago, "Wool, a Study of the Fibre," which was published under the auspices of the Empire Marketing Board. He did not think he ever read any scientific work which was so good.

THE MEASUREMENT OF WOOL AND ITS PRACTICAL SIGNIFICANCE

By S. G. Barker, Ph.D., D.I.C., F.R.S.E., F.T.I.
(Director of Research, Wool Industries Research Association)

On the occasion of the conclusion of an era in the history of any institution it is perhaps appropriate to review the state of our comparative ignorance with regard to subjects affecting the welfare of the industries we serve. Thus one might estimate the basis on which the future could be built, and whilst not indulging in flights of prophecy or conjecture, yet might indicate possibilities for development. The basis of the industry is, of course, its raw material, and it must be remembered that methods of manipulation have to be devised to meet the vagaries, characteristics, and attributes of the fibre which is being treated.

The early days of the wool industry began with manual manipulation; the hand-loom, the hand-card, and hand spinning all preceded the mechanical efficiency which we have attained to-day. It is obvious, therefore, that at the commencement of scientific investigation with regard to the wool fibre in the sixteenth century, the workers naturally attempted to relate the characteristics of the fibre to those uses to which it has been put in practical everyday life. Of these the milling and felting properties of wool seemed almost dominant factors. The earliest workers, therefore, began by making attempts to relate the attributes of the fibre to its milling and felting power.

In 1665 the Royal Society in London had its attention drawn to the question of hair and wool structure in a series of papers by Hooke, and it is of interest that in Observation 4 of his *Micrographia* he records the conjecture that it might be possible to spin a kind of artificial silk out of some glutinous substance. Not only in this country, but abroad also, scientists were paying attention to hair and fibre structure, and about 1675 Malpighi published a book on this subject, whilst in the earlier part of the seventeenth century our Royal Society once more devoted their attention to fibre measurement in the dissertations presented to them by Henry Baker. It is probable that these earlier workers had little connection with the industry itself, and in 1777 there appeared what might be styled an epoch-making work by Daubenton in France, in which, for the first time, the attributes of the wool fibre were measured and an attempt made at classification. It would perhaps be of interest in this paper to record verbatim Daubenton's remarks with reference to the necessity for such fibre measurements—

> "The products of nature can only be graduated roughly by the use of our senses, and in absence of instruments or apparatus we cannot work to any great accuracy. In order to obtain sharper and clearer results than those of the naked eye, scientific

apparatus must be used and then comparisons can be effected between the characteristics of different types of wool, not only as regards their fineness, but in other directions."

So long as the standardisation of wool quality is carried out by mere human agencies unaided by scientific apparatus, there will be a danger for commercial transactions to be carried on with considerable risk. Daubenton speaks of the risks of the manufacturer and the necessity for methods of measurement and technique to be developed in Overseas wool, but at the same time forecasts considerable risk to the manufacturer and the purchaser unless standard methods are put forward. He pointed out that there is no guide as to the significance of wool fineness in relation to manufacture, and even if the difference between two superfine types of wool was known, it would be impossible to interpret this difference to the sheep breeder, so that he would still go to work blindly.

In between the coarsest and finest wool he formulated a graduated scale for wool and attempted to relate it to its manufacturing power. He classified wool into six grades—superfine, fine, half-fine, medium, half-coarse, and coarse wool—but he said that there was no certain rule by which you could differentiate between adjacent classes. He speaks of the necessity for blending in practice, and hence a classification as far as manufacture is concerned becomes difficult. He finally reduces the number of classifications to five—superfine, fine, medium, coarse, and super-coarse. He says that this is a definite nomenclature that can be followed and manufacturers will understand it. He suggests that these be called prima, secunda, and so on.

About the same time Monge, in France, was the first to assert that the surface of wool is formed of little plates which cover each other from the root to the point. He attributed to the scales the milling and felting power of the fibre and propounded a theory of milling and felting very much akin to that which is still proposed to-day, knowing as he did the similarity between the unidirectional motion of the fibre in felting and the progress of an awn of wheat through a fabric.

In this country a great impetus was given to fibre measurement and classification by the investigation of the comb, and it is no mere accident that in the years following 1790 there was considerable anxiety expressed as to the precise geometrical attributes of the fibre which would influence the fineness or levelness of the yarn produced.

We thus find that about the years 1805–10 considerable activity was evinced in this country, due possibly to the work of Parry, Bakewell, and others on the production of wool of known dimensional characteristics, and an attempt was made to relate these characteristics to subsequent manufacturing performance.

To go through the list of the hundreds of workers in the eighteenth century would be impossible in the time at my disposal and has already been done by me elsewhere. At the same time one or two outstanding features should be noted.

In the period following the conclusion of the Napoleonic wars, more especially in the years from 1820–35, there was the greatest possible activity with regard to wool research for the discovery of methods for determination of its dimensions.

Young, 1824, utilised the diffraction method developed by Ewles a century later, and now, I note, adopted by certain workers in America. The Dollond eriometer, or wool measurer, was already suggested, whereas methods had been developed such as, for example, the setting up of a fibre on a dark background and walking away from it until it was just invisible.

In 1831, Grawert, a watchmaker on the Continent, suggested a novel method for measuring fibre fineness. The fibre was attached to a weight and acted as the pendulum of a clock. It was held between two clamps capable of movement with a micrometer screw. As the clamp was gradually released a position was obtained where it no longer held there, the pendulum moving forward to stop the clock at once.

In 1837, Youatt published his book on wool, a treatise which I would suggest might easily be republished to-day, since its conclusions and findings are still of

prime significance. About this time the idea of wool classification on a basis of fibre fineness was gaining ground in all parts of the then known world. It is significant that the first bales of Merino wool were arriving in England from Australia and there seemed to be a great development of wool production throughout the rapidly-growing British Empire. At the same time the need for some guide as to the type of wool required by the manufacturer was evident to all, and the German workers of that time were not slow to point out the danger to the manufacturer, and also to the farmer, of the production of wool which might not meet the requisites of the market.

In 1823, to clear up all misunderstanding, a conference of farmers, manufacturers, and merchants was held at Leipzig at which an instrument was exhibited for the measurement of fibres, which consisted of laying 100 fibres in a groove, compressing them with a weight, and by means of an indicator measuring the compression. The average thickness of the fibre was thus estimated. It is significant that last year at the International Wool Conference in Liège our friends from Czecho-Slovakia introduced an instrument known as a Rapid Lanometer which involved exactly the same principle. Following the conference at Leipzig, the German developments as regards fibre measurement were directed towards affording means for the farmer for measurement of his wool and attempts were made to reconcile microscopic measurements with practice, and they singularly failed.

Probably one of the outstanding features about that time was the work of Herman v. Nathusius and Wilhelm v. Nathusius who quickly realised that fibre measurement was not going to produce the millennium in the industry. Once again it is significant to note that a fibre rotator was used and that the question of ellipticity of the fibre was noted and given its proper significance by these workers.

In 1867 we find attention being paid to the question in America, and the work of Burgess and others on hair and wool was the beginning of an era of research in that country.

In 1873, Bohm paid attention to crimp and constructed a crimp measurer which consisted of a number of scales with serrated edges corresponding to the troughs and crests in the crimp wave of the fibre. He made a brass plate with nine sides, each side of which had a different number of serrations, and by placing these against the fibre in the lock he estimated the number of crimps per inch.

It is again significant that in 1929, Duerden in South Africa brought forward the same method once more.

In 1885 we find the work of Bowman in this country recorded in a treatise on the scientific attributes of the fibre. In the years which follow we find a variety of workers all bent on attaining the same goal.

Let us now review the position as we find it in the period immediately after the war. Once again during the decade of 1920–30 we find a vigorous revival of textile research similar to that which occurred during the corresponding period of the century previous. To mention names of workers would be invidious but during that period the work of the textile Research Associations began to make itself felt. If one might offer a word of criticism the methods adopted by the various workers right away up to 1926 would seem to be what was almost an obsession for the microscope.

Let us therefore review something of more recent work on this subject and attempt, if we may, to ascribe their true significance to those characteristics of the fibre which we can now measure with certainty.

To trace the history of fibre measurement we should need to discuss the work of something like 1,000 workers who have published papers throughout the world on this subject. It would seem as though the word "wools" has obsessed our predecessors with the idea that the external attributes of the fibre were the most important. W stood apparently for width, O for oscillations or crimp, O again for ovality, L for length, and S for scaliness. Unfortunately our earlier workers

could see no further than these characteristics, but at the same time, they were probably right to a large extent. The failure of the previous workers to correlate the different dimensional characteristics of the fibre, or to find any definite linkage or connection with manufacturing practice, has been due largely to the fact that they have been measuring or assessing the external values of the fibre in terms of the wrong dimensions.

Work on gravimetric methods begun about the middle of the last century and again revived by Wilkinson and others, culminated in the establishment of the exact value for the density of wool by A. T. King, of the Wool Industries Association, which established a method independent of the microscope for the assessment of fibre fineness.

It is now generally acknowledged that the weight in milligrams of ten metres of fibres at standard regain of 18¼% is a safe criterion for assessing and comparing fibre fineness. The gravimetric method now suggested consists essentially in taking fibres, say five hundred or so, cutting them very quickly with a razor blade to a known length, an operation which takes but one second or two, and afterwards weighing a known number of these lengths under standard conditions. Taking this gravimetric method as the standard procedure, it is possible to differentiate between one quality and another on the basis of fibre fineness alone. It is obvious that in weighing a fibre or bunch of fibres one needs an average value for the fineness, independent of the shape or contour of the fibres themselves, which gives a value of an average character taking into consideration the whole length of the fibre and not merely, as in the microscope measurements, the fibre thickness at a point.

Quite recently the International Wool Conference in Bradford interested itself in the question of the possibility of putting forward an International scale of fibre fineness. There were obvious difficulties in the way, in that each country in the world had its own particular methods of sorting to further its own particular requirements. It was obvious, therefore, that if any agreement was to be obtained between country and country, first of all an agreed technique of fibre measurement must be employed. The difficulties in getting agreed microscopic technique were enormous, but in the case of weight per unit length no such difficulties ensued.

Let us now turn to some of the results of following this procedure. The British Wool Federation, some time ago, in agreement with the United States of America, selected certain tops as representative of certain qualities, and these have been multiplied in America by manual methods to put forward an agreed series of standards. By the kindness of the Wool Federation we were permitted to examine these tops, and employed the method outlined above. It was found that in proceeding from one quality to the next there was not just haphazard selection but a mathematical law seemed to govern trade practice.

A very interesting relationship was found to exist between the average fineness of these standard English combed tops and their position in the scale of qualities. The same relationship may also be shown to hold in principle for the French, German, Italian, and other Continental standards.

The values of fineness used to establish this relationship are those which have recently been published from this laboratory as the results of measurements on a range of tops which have been selected as typical of each quality by the trade itself.

It has been found that a linear relationship exists between the logarithm of the average fineness of a top expressed as the weight of ten metres of fibre, and its position in the scale of qualities, when equal intervals are assumed between these qualities. It is convenient to ascribe the numbers 10, 9, 8......2 to the qualities 48's, 50's, 56's......80's, thus providing, if necessary, for two qualities above 80's. The relationship found is true from the highest down to the 48's quality. The result of plotting the logarithm of the weight/length ratios of fineness against the position of the top in the scale of qualities according to the grade

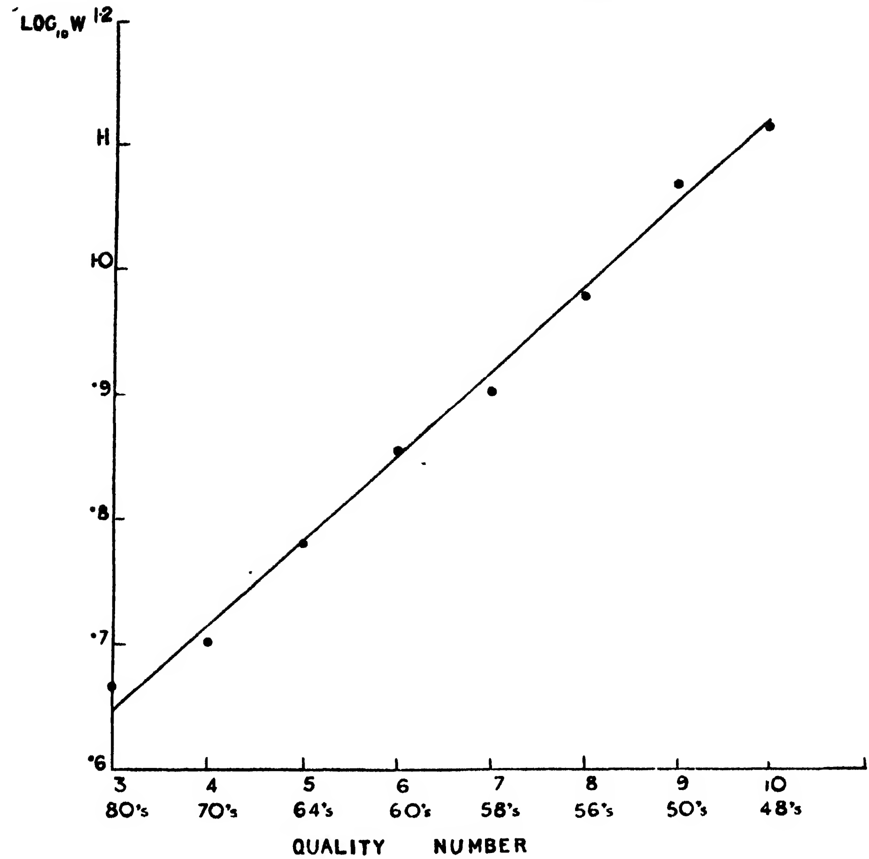


FIG. 1

numbers above, gives a straight line graph. In the case of the thicker wools, if the values obtained from direct cross-sectional measurement are substituted for the weight/length figures, close approximation to the linear relationship is obtained throughout.

The best values for the constants of the line passing through these points have been calculated by the method of least squares. It then appears that the relation between fineness and quality for British tops is expressible by the equation—

$$x = 14{\cdot}79 \log_{10} \frac{W}{L} - 6{\cdot}58 \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where the successive values of x (10, 9, 8, etc.) represent the qualities 48's, 50's, 56's, etc., and where $\frac{W}{L}$ is the weight in milligrams of ten metres of fibre taken at a regain of 18¼ per cent.

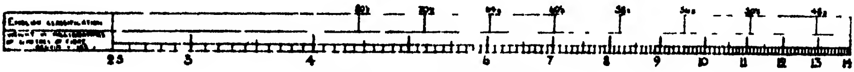
Equation (1) may also be written in the form—

$$\frac{W}{L} = e^{(x - 6{\cdot}58)/6{\cdot}43}$$

from which it is apparent that on substituting the successive values of x, namely, 3, 4......10, the scale of fineness becomes in reality a series of values in geometric progression with a constant ratio—

$$r = e^{\frac{1}{6{\cdot}43}}$$

Equation (1) is very useful. Once the mean fineness of a top is known, its position on the English scale of standards may be readily obtained. Conversely, the mean fineness of any top conforming to the standards may be found by substituting the corresponding value of x. The relationship expressed by the equation also lends itself very well to diagrammatic treatment. If the fineness readings are marked off on a logarithmic scale, such as a slide rule provides, the mean values for the different qualities will occur along a collateral scale at equal intervals. It is thus quite easy to construct a fineness scale from which values can be read off instantly. (Fig. 2.)



SCALE OF FINENESS

FIG 2

In wools of coarser thickness than would be classified as 48's quality, the presence of medullated fibres would, of course, render the weight per length method for measuring fibre fineness somewhat unreliable, owing to variations in fibre density. In such cases contour measurements are more accurate for thickness determination, as shown above.

French Standards

The figures for French standards put forward by MM. Dantzer and Roehrich, after examination of a range of French tops, are found now to conform to the same law as that expressed by equation (1), with, of course, a difference in the constants of the equation necessitated by a different nomenclature. MM. Dantzer and Roehrich have employed the numbers 17, 16, etc., to correspond to the French qualities 150, 140, etc., a nomenclature in the opposite direction to that employed for the British values

Using their values in the same way as for the English tops, it was found that the relation between fineness and quality for French tops may be represented by the equation—

$$x = 23{\cdot}30 - 15{\cdot}77 \log_{10} \frac{W}{L} \qquad \text{.....................................(3)}$$

This relation holds from the finest down to the IV's quality. In this equation x signifies the quality according to the nomenclature of MM. Dantzer and Roehrich, i.e. the thicker fibres were given the lower grade appellations, and $\frac{W}{L}$ the weight in milligrams of ten metres of fibre taken at a regain of $18\frac{1}{4}$ per cent.

German Standards

Plail (1930) published a scale of fineness expressed in terms of average fibre width in μ, after numerous measurements had been carried out on raw wool and tops. Allotting to the qualities 4A, 3A, etc., the numbers 1, 2, etc., as before, it may be shown that the relation between fineness and quality for wool used in German commercial practice (as given by Plail) is expressed by the equation—

$$x = 16{\cdot}15 \log F - 17{\cdot}96$$

where F represents the mean fibre width in μ and the successive values of x 1, 2, 3......11, the qualities 4A, 3A, 2A......F. Krais' figures for weight per length values give a similar result.

Italian Standards

In view of the foregoing it is interesting now to consider the Italian proposals put forward by Commander Schneider at the Bradford meeting of the International Wool Conference in November 1929. He suggested a fineness scale in which the successive degrees or grades differ from each other according to the law of geometric progression. In this case the equation connecting the quality, and the mean fibre width may be shown to be—

$$x = 55{\cdot}88 \log_{10} F - 66{\cdot}00$$

where F, as before, stands for the mean fibre width in μ, and the values of x (1, 2, 3)......express what Schneider calls the "Finesse."

All the four systems of finenesses which have been dealt with above differ both in the number of grades they employ and in nomenclature Each system has been evolved from the needs of the particular country it serves and yet all, as we have shown, have one feature in common, viz., the progressive scale of fineness in each country is in geometric progression. It would seem that there should be some fundamental reason for this mathematical relationship. To understand this it is necessary to remember the manner in which the wool is first graded into the different qualities. This highly skilful work is done by the sorter, who, using both eye and hand, sorts out the wool into the qualities or grades which custom has established in his particular country. The question to be answered is, why do the finenesses of these grades form a geometric progression? In 1860, Fechner in his "Elements der Psycho-Physik," put forward the law now known as the Fechner-Weber law, which states "in order that the intensity of a sensation may increase in arithmetical progression the stimulus must increase in geometrical progression." This law, holding good between certain limits only, is expressed in his general formula $I = C \log S$, where I stands for the sensation and S for the stimulus and C is a constant. If we regard the woolsorter's judgment as indicative of I then it must immediately follow that any attempt on his part to form a gradation of finenesses will result in a scale in which successive finenesses increase in geometric progression. This, as we have shown, is exactly the case in practice in all countries.

It must, of course, not be forgotten that two senses are employed in woolsorting, viz., sight and touch, and that Fechner's law has recently been shown by Macdonald and Robertson to be inapplicable to the tactile sense. Thus the result of a selection employing the visual sense would produce a gradation of wool into classes whose mean finenesses are in geometric progression. The tactile sense may in some way be related to the question of "handle."

It is thus established by examination of results that for woolsorting the eye, or the visual sense, is the paramount factor. There arises, therefore, a question of the physiological aspect of the case. This has been dealt with fully by Tänzer in 1925 in a discussion on the psycho-physiological aspects of woolsorting. The conclusions arrived at in his thesis showed that in the case of woolsorting the question of visual acuity of the eye was somewhat complicated, since it was not a matter for the distinction of individual fibres from one another, but for the differentiation of them enmeshed together in the mass. The problem assumed a different aspect according to whether raw wool, grease wool, or scoured wool was handled. The question of suitable illumination during the woolsorting operation becomes a matter of prime importance. A good scattered light from shaded sunlight or from a north window would, with a minimum amount of fatigue, facilitate the differentiation between one set of fibres and another. In a shaded or darkened room one is conscious of an opening of the pupil of the eye with a consequent feeling of strain, so that in inadequate light a fibre would appear somewhat thicker owing to the greater angle subtended at the eye. A great factor in differentiation between one filament and another as regards size is a sufficient degree of contrast. A white fibre on a black background is capable of being better judged than a black fibre viewed under the same circumstances. This is obviously a case of irradiation from the fibre itself. Under these circumstances the discussion of the physiological side of woolsorting resolves itself primarily into the question of suitable illumination, and suitable optical power of the eye, so that the fibre may subtend an angle at the eye by which its size can be assessed.

A further question arises in that the mesh and the size of the interstices of the mesh have also to be considered. Obviously a well-opened wool can be differentiated for fineness better than a closely packed one. Apart from the work of Tänzer, Helmholtz, in his "Treatise on Physiological Optics," and Hartridge, in a paper on "Visual Acuity and the Resolving Power of the Eye," have fully

discussed the question of the differentiating power of the visual sense for small changes in the size of the objects under view. The subject is far too complex to be entered into further here without lengthy treatment, and the reader is referred to the original treatises as set out above. It can be said, however, that for the normal operation of the woolsorter the Fechner psycho-physical law is the fundamental basis of his work.

Before proceeding to summarise the practical outcome of the psycho-physical law one would naturally point out that unification of nomenclature is necessary. Dantzer and Roehrich have adopted a system by which the finest wool was given the highest grade index, which is of course in consonance with trade practice to-day. For purposes of their work, England (Winson), Germany, and Italy used the opposite system, the finest wool was given the lowest index number. In accordance with trade practice throughout the world, and bearing in mind the original meaning of quality numbers, it may be better to adopt the French system, and to allow the higher numbers to represent the higher degrees of fineness. This is a matter, however, to be decided by the trade itself.

The formula given by Fechner, $I = C \log S$ finds its counterpart in the different system of classification for each country as below—

England	(Wt./Length)	...	...	$x = 14{\cdot}79 \log_{10} \frac{W}{L} - 0{\cdot}58$
France	(Wt./Length)*	...	...	$x = 23{\cdot}30 - 15{\cdot}77 \log_{10} \frac{W}{L}$
Germany	(Fibre Width)	...	...	$x = 16{\cdot}15 \log_{10} F - 17{\cdot}96$
Italy	(Fibre Width)	...	...	$x = 55{\cdot}88 \log_{10} F - 66{\cdot}00$

* Reverse system of enumeration employed

The agreement of commercial practice with the psycho-physical law of Fechner and the mathematical laws shown above may be regarded as the fundamental basis of woolsorting in all countries. This being known, a convenient and secure starting point is afforded for the discussion of an international scale of fibre fineness capable of interpretation by all countries, without in any way disturbing current trade practice.

The fact that the psycho-physical law, as put forward by Fechner and Weber, is obeyed in all countries where woolsorting is practised, is of the highest importance. It is now possible to construct a table showing the relationship between the values obtained by different methods of woolsorting in various parts of the world, and at the same time, since they are based on a logarithmic scale, to utilise equal scalar gradations for equal differences of quality. The results of this show, in the first place, that fibre fineness is the paramount feature in woolsorting, whereas other attributes of the fibre become the second consideration. Nevertheless the latter are by no means negligible, and once the quality is assigned as far as fineness is concerned, then come the sub-divisions, according to the influence of other attributes, which are of the highest importance to the trade. It is the classification of the various wools in these sub-divisions which render so difficult the assessment of the various attributes in exact figures, as also the prediction of the subsequent manufacturing performance of the wool from the numerical values obtained for its different characteristics. The influence of these other factors on the practical man's judgment in valuing wool is of such great importance that we must now discuss some of them. They may be divided under the three headings set out at the beginning, namely, the dimensional, structural, and constitutional characteristics affecting wool quality.

Let us first of all, therefore, consider the inter-relationship of those dimensional attributes of wool which would fall within the scope of the definition of wool "quality"; namely, crimp, contour, length, and scaliness.

It is significant that the earlier workers sought to account for all phases of the manufacturing behaviour of wool in terms of dimensional or geometrical attributes, the possibility of variability of the fibre substance or material, or even its internal physical structure, seeming to them remote, possibly the natural corollary

to the purely mechanical manipulation of the fibre, which was customary in manufacture, the chemical and other processes being incompletely developed.

Crimp or waviness follows as another outstanding feature, although it is doubtful whether in the eye of the woolsorter crimp actually indicates much more than an additional check on the fineness of the fibre.. The Wool Industries Research Association has devoted considerable time to the study of crimp. It is found that in the same lock of wool the total number of crimps per fibre is the same regardless of the length of the fibre. This discovery means that the formation of crimp is a periodic function of time itself. Under these circumstances, one can foresee new lines of discovery regarding crimp formation. It is well known that crimp or waviness can be formed with organic materials by purely chemical or physical chemical reactions Is it not possible that biological factors in crimp formation may be subordinated to those of chemistry or physics?

In the second place it can be put forward that the length of a wool fibre from a lock, exhibiting different lengths, is intimately related to the thickness of the fibre; that is, crimp, length, and thickness can be correlated in the same lock. Duerden has used crimp as a method for the estimation of wool quality on the animal itself, and possibly it is a rough guide. It certainly may be a fairly reliable guide if a physical chemical reaction in the fibre substance itself can be proved as the source of the waviness.

To deal with the inter-relationship of the attributes of the fibres as expressed by wool quality, one might take an analogy in the behaviour of a strut or beam under strain subjected to a pressure along its length. The amount of bending is given by a well-known mathematical formula, and arising out of this one can obtain a formula relating crimp, thickness, the shape of the fibre and its elasticity. These four factors multiplied together under certain conditions yield a constant value, and it has been established that the constant is somewhere about 9×10^6. Thus we have the two fundamental laws underlying wool manufacture and woolsorting to build upon for our subsequent work

First of all the law of woolsorting as regards fineness is known, and secondly a law of woolsorting as regards its relationship to quality is also under investigation. There is, however, in the second law, a factor which is of dominant importance, namely, we introduce a new item in the assessment of wool quality, the idea of elasticity. Elasticity is a factor dependent on the structure and constitution of the fibre. Thus it is obvious that in any discussion of wool quality the constitution of the fibre must be recognised, and duly attributed to its proper place, a point which, as already mentioned, received scant attention from earlier workers, resulting in their failure to relate scientific experiment and commercial practice.

With regard to contour or shape of the fibre, although in the past regarded as being of little practical importance, recent research has shown its circularity to be a contributory factor to a good spin or otherwise. It is certain, however, that in a recent examination of wool sent to Torridon by the New Zealand Government all those wools which were classified by the Bradford wool man as being a good sound proposition had the lowest ellipticity values, and the highest sulphur content. High sulphur content in wool has been said to be analogous to high sulphur content in rubber, that is, a high degree of vulcanisation gives the rubber high elasticity and manufacturing value— similarly with wool.

It is significant that Bradford commercial practice fits in with the laboratory results so well as to show that first of all shape and secondly constitution confirm the results of the considered judgment of the practical man.

Under these circumstances one can claim, therefore, that the discoveries made at the Wool Industries Research Association are leading surely to the elucidation of the enigma known as "wool quality," but at the same time one has to bear in mind that no comparison of one attribute alone will yield the solution, but only when a method or methods are devised for assessment of all qualities together can reliable laboratory work, confirming the results of the practical man, be obtained.

Even then it is obvious that in dealing with mass production, microscopes and the like are unsuitable implements, and that the work of the woolsorter, born of experience, and which in the past has worked so well in commercial practice, will prevail. The only difference will be that, as is commonly found, since sound commercial practice has always a definite scientific basis, that once this basis is known it opens out the way for improvement of the raw material in its various essential attributes for the attainment of greater uniformity of the fibre itself, and consequently for the attainment of a higher degree of excellence and accuracy with a consequent benefit in production of manufactured goods. Previous, however, to any method which may be agreed upon for the determination of wool quality, there must be agreed methods of sampling. These are of the highest importance. J. A. F. Roberts, of the Wool Industries Research Association, has recently published a paper on this subject and it is hoped that work now in progress will ultimately solve the question of sampling once and for all.

The Chairman said that he was sure members present had heard these two papers with great interest, and invited discussion and questions. Several members having asked questions and expressed their appreciation of the lectures, a vote of thanks to Dr. Gibson and to Dr. Barker was proposed by Mr. John Crompton and seconded by Mr. W. Scott Taggart. This was heartily accorded.

Replying to the vote of thanks and to the questions asked, Dr. Gibson said it had been a pleasure to him to deliver the lecture and to endeavour to give an idea of the general trend of research work in connection with flax, and he was very grateful for the way in which it had been received. In regard to the question as to the lines of work they were engaged upon, he thought that it would be realised that to answer all the points raised would take the rest of the day. What was going to happen with regard to the coarse type of flax was a serious matter. He had tried to make it clear that they were getting sufficient quantities of the coarse and lower qualities from Russia, but he was not sure whether the supply would continue when things reached a state that might be regarded as normal. A great deal depended upon the price at which low quality fibre came to rest. He did not think anybody could say what that would be. One of the possibilities at which he had hinted was the development of a dual-purpose flax. Immense supplies of low-quality fibre might be available from that. He was inclined to agree that co-operation between user and research worker was of the greatest importance. If the industry would do what the user wanted, processes of manufacture could be considered from the point of view of getting what the user wanted and considerable changes could be made. The producer was prone to set down methods of manufacture and quite naturally became conservative, not liking to make alterations. Another questioner had mentioned the configuration of the fibre. In the linen industry the problem of the optimum configuration of the fibre was as varying, he was afraid, as in the cotton industry, because they began with a fibre strand which was a bundle of fibres. During the preparing process these were split up into finer strands which were still a compound of individual fibres, so to decide the optimum they had to consider this compound fibre strand, and, of course, the individual units of which it was composed. They were giving rather more consideration to the behaviour of these fibre strands during processing with a view to facilitating spinning. His colleagues were giving consideration to the requirements of the user and trying to decide what type of individual fibre gave the most suitable fabric for specified purposes.

Dr. Barker said the question of constant density had been discussed by several authorities. Dealing with the comparison of different wools for spinning, he said that during the past twelve months they received from New Zealand 200 fleeces of all types of wool and 180 fleeces from South Africa. They were submitted individually to wool men in Bradford, who indicated whether each fleece was good, medium, or bad, according to trade opinion. Then each fleece was analysed, and every fleece described by the Bradford men as "good spinning"

or "good manufacturing proposition" had a low figure of ellipticity. Alternatively every "bad" fleece had a high figure of ellipticity. Again, every "good" fleece had a high sulphur content, and "bad" fleeces a low sulphur content. The case of cotton was no doubt different.

The afternoon was spent in a visit to the Manchester Ship Canal. Members were conveyed by motor coach to No. 8 Dock, where officials of the Ship Canal Company met the party. One of the Company's tugs was then boarded and the party was conveyed around the docks and along the Canal to Barton Bridge. A very pleasant outing was thus enjoyed.

Public Lecture in the Houldsworth Hall

In the evening a public lecture was delivered in the Houldsworth Hall, Deansgate, Manchester, by Sir Leonard Hill, M.B., F.R.S., on the subject of "Clothes in Relation to Health." Mr. Frank Nasmith, F.T.I., Chairman of the Council of the Institute, presided.

NOTES AND NOTICES

Scottish Section Committee

In our reference in last issue to the proceedings of the annual meeting of the Scottish Section of the Institute—at Edinburgh on 14th March last—the names of the Section Committee were recorded and one name was included subject to acceptance. Acceptance having since been notified the complete list of the Committee is as follows—Messrs. J. Macpherson Brown (Galashiels), A. R. Geary (Dunfermline), T. M. Lees (Galashiels), A. Smith (Dundee), A. J. Hall (Pollokshaws), with A. W. Blair (Hon. Secretary, Glasgow) and J. P. Beveridge (Member of Council, Dunfermline) as *ex-officio* members. With regard to Section meetings for the ensuing session, the Committee is to consider arrangement of visits to Dundee and Musselburgh.

Employment Register

The following announcements are recorded from the Employment Register of the Institute. Further particulars may be secured or applicants placed in direct communication on request—

No. 54—Appointment required as buyer or salesman in textiles: six years in important buying department; fluent French; age 24.

No. 55—Age 34; first-class education; 14 years with coloured goods manufacturers as salesman and assistant in general supervision of departments. Had control of costing and statistical department and accustomed to counting-house.

No. 56—Age 30; A.T.I.; experience in sales, production, and designing. Medallist in Section B, Cotton Weaving, City and G.; prize winner for fabrics (Text. Inst. and L.C.C.); scholarship winner; evening teacher in weaving subjects; mill experience.

No. 57—Textile chemist and physicist desires appointment; experience in artificial silk.

Institute Membership

At the March meeting of the Council, the following were elected to membership of the Institute—N. H. Chamberlain, 4 Buckingham Mount, Victoria Road, Headingley, Leeds (Research Assistant, Department of Textile Industries, Leeds University); J. M. Freeland, 12 Albertville Drive, Belfast, N. Ireland (Clerk, York St. Flax Spinning Co. Ltd., Belfast); W. Jerome, 6 Park Grove, Frizinghall, Bradford (Student); S. M. Roberts, Wellwood, Selkirk (Apprentice Manufacturer); S. Shann, 30 Scotchman Road, Heaton, Bradford (in training for Management of Spinning Department); J. Whittle, 205 Church Road, Smithills, Bolton (Mill

Manager, Barlow & Jones Ltd., Bolton); A. C. Goodings, Ontario Research Foundation, 47 Queen's Park, Toronto 5, Canada (Director of Textile Division).

At the April meeting of the Council, the following were elected to membership of the Institute—J. Butterfield, 15 Water Street, Hapton, near Burnley (Textile Machine Erector); H. J. Clarke, Selfridge & Co. Ltd., 400 Oxford Street, London (Staff Manager); H. Hibbert, Lodge Bank Works, Darwen (Textile Engineer); A. S. Moss, "Dimsdale," Greenhill Crescent, Elderslie, Renfrewshire (Textile Chemist); R. A. Murray, E. Hall & Bro. Ltd., Botany Bleach Works, Whaley Bridge; A. H. Scowcroft, 14 Lever Edge Lane, Bolton (Clerk, Cotton Mill); M. H. Winder, 40 Lodge Lane, Hyde (Cotton Manufacturing, Manager's Assistant).

COMMUNICATIONS

"Theory and Electrical Drive of the Loom"

To the Editor

Sir—The statements contained in the letter by the Reviewer of "Theory and Electrical Drive of the Loom," published in the *Journal of the Textile Institute*, March 1931, pp. P35–P36, again need correction.

It may interest the Reviewer to know that the sley of that particular 120-in. loom was actually only 2 in. longer than the average figure given in the book, and also that the other particulars of that loom were practically identical with the average values stated. Consequently it may be correctly claimed to be representative of average modern practice.

The figure of 1·16 h.p. given was the average (or mean) value over 38 hours of the *R.M.S. power* required to drive the 120-in. loom (being obtained from the analysis of a complete power record taken over that period) and therefore is comparable with the calculated *R.M.S. value* of 1·09 h.p. (Table XXXIII).

Since the calculations made have been proved conclusively to compare very closely with a large series of experimental tests carried out over a number of years, to question the data on which the calculations are based seems quite unnecessary, for, as stated on page 89 of the book, "these values have been calculated on the basis of average dimensions and weights of loom parts given by several reputable firms of loom manufacturers in this country, and therefore do not necessarily hold good for *all* looms of the reed-space given. Each specific case should be considered individually, and calculations made in a similar way to those given."

Humberstone, Leicester, (Signed) R. H. Wilmot
31/3/31.

Reviewer's Reply

Sir—Replying to the points raised by Mr. Wilmot in his letter of 31/3/31.

Length of 120-inch Loom Slay—I have looked through the book, but cannot find any average figure given for this. But the information now given has no bearing on my original criticism, which was that if the shuttle of a loom of 120-inch reed space moved the distances calculated by Mr. Wilmot, the slay length would be about 1 foot more than the average slay length in practice for that size of loom.

Power for 120-inch Loom—If the figure 1·16 h.p. given was the average of the *R.M.S.* power, why not state that fact and avoid misunderstandings?

Accuracy of Data—I was aware of the statement on p. 89 of the book that "these values have been calculated on the basis of average dimensions and weights of loom parts given by several reputable firms of loom manufacturers in this country." But if so, then in a good many instances, of which I gave examples, the particulars given do not agree with the average looms at work in the country. (Signed) W.A.H.

College of Technology,
Manchester, 20/4/31.

// THE JOURNAL OF THE
TEXTILE INSTITUTE

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PROCEEDINGS

ANNUAL GENERAL MEETING OF THE TEXTILE INSTITUTE
Mr. GEORGE GARNETT, J.P., ELECTED PRESIDENT
COUNCIL ELECTION: RESULT OF BALLOT

The 21st Annual General Meeting of members of the Institute took place at Headquarters, Manchester, on the 20th May. Lieut.-Col. B. Palin Dobson, the retiring President, occupied the chair at the outset.

The Council's Annual Report, after minor amendment, was adopted. The report was as follows:—

COUNCIL'S ANNUAL REPORT

Not only have the well-established forms of activities of the Institute been fully maintained during the past year, but in certain directions advances and developments have been recorded. Considerable expansion has occurred in the *Journal* in comparison with previous years, especially in the publication of results of new experimental work. The Annual Competitions for designs of woven fabrics and for specimens of yarns have been further developed. A new Scholarship open to young craftsmen engaged in cotton spinning or weaving has been established. A Medal has been added for occasional award in relation to published investigation in Textile Technology. The Library of the Institute has been further developed, and a printed catalogue provided, a convenience which has met with widespread appreciation, judging by the increased use of the postal system of loan of publications. The accommodation at the Headquarters premises is gradually becoming inadequate to the requirements, and the problem involved is receiving earnest consideration.

Balance Sheet and Accounts

The Annual Balance Sheet and Accounts (to 31st December, 193[illegible]) which accompany this report will be reviewed by the Hon. Treasurer in his annual financial statement at the next Annual General Meeting, which is fixed to take place at Manchester at 4 p.m. on the [illegible]th May. The Council regrets that the Revenue Account for the past year shows a deficit, and steps have already been taken with a view to reduction of expenditure for the present year. In a year which embraces the fitting celebration of the "Coming-of-Age" of the Institute, the difficulties in this connection are increased. However, the generous response of Members both at home and abroad to the special Celebrations Fund appeal has been of very great assistance to those concerned with the control of the Institute's finances. In view of the depressed state of trade and general financial stringency, the Institute has done well in maintaining its position, and it is confidently hoped that increased membership will continue to be recorded in future years. The excellent policy of the Finance Committee in conserving available resources is now proving decidedly beneficial. Reference was made last year to the new demand of the Inland Revenue authorities whereby the Institute can no longer maintain classification as a charity. Not only has liability to income tax been claimed from the year of definite withdrawal of the classification in question, but retrospective claims have been presented. The claims have been appealed against, and it is hoped that final settlement may not be unsatisfactory.

Annual and Other Meetings

The Annual General Meeting, which is not necessarily held regularly at Headquarters, took place at Bolton in May, when Lieut.-Col. B. Palin Dobson was re-elected to the presidency. The Mayor (Councillor R. F. Roberts) honoured the event and the local Education Committee kindly allowed the principal meetings to be held at the Technical

College. In the course of the proceedings, medals for services to the Institute were awarded to Messrs. J. Crompton, W. Frost, F. R. McConnel, and T. Fletcher Robinson. The Annual Mather Lecture was contributed by Mr. H. G. Hughes, Director of the Cotton Trade Statistical Bureau.

Journal of the Institute

The Publications Committee has during the past year continued its general policy of publishing in the Transactions portion of the *Journal* contributions of high intrinsic scientific value. At the same time, much careful attention has been given to matters of general interest to the average member of the Institute. The Proceedings section of the *Journal* has included a large amount of such matter and the Publications Committee will not cease to give this portion of the *Journal* that consideration which the importance of the matter properly warrants. The Committee has been impressed with the large number of original papers embodying the results of research of a high scientific order. While it has welcomed the increase in matter, it has at the same time necessarily had to deal with a consequent difficult financial position In all the circumstances, the general financial position of the *Journal* is considered to be good, and particularly the Committee would point out that the actual revenue from advertisements is this year in excess of any year during which the *Journal* has been published.

The volume of matter published is indicated by the following figures, with the 1929 figures in brackets—Proceedings 204 pages (192); Transactions 612 pages (410); Abstracts 692 pages (692); and advertisements 290 pages (304). The number of subscribers to the *Journal* is well maintained and sales of back issues are constant. The effects of the industrial depression have undoubtedly been felt, but under all circumstances the position is regarded by the Publications Committee as satisfactory.

Institute Diplomas

The scheme of professional qualification of Members of the Institute continues to claim appreciation and recognition in a highly satisfactory manner. Applications for the Associateship and Fellowship have come forward in increasing number and the Examinations in relation to applications for the Associateship may be said to have developed into well-established tests in General Textile Technology by way of qualification supplementary to attainments in specialised courses in textiles. This is evidenced by the references to the Associateship qualification appearing in a number of the prospectuses of technical colleges. In the case of short summer course for textile teachers held annually under the auspices of the Board of Education and conducted by Mr. J. E. Dalton, H M I., the announcement for the current year states that a course in textile subjects will be held in London from 18th to 31st July and the course will be mainly devoted to the study of General Textile Technology in its various aspects, including its relation to school curricula, and to the conditions laid down by the Textile Institute for the award of the Associateship.

Applications for Institute diplomas during 1930 totalled 69 (15 Fellowship and 54 Associateship) as compared with 52 in the previous year (11 Fellowship and 41 Associateship) and 48 in 1929 (20 and 19), bringing the total number of applications since the inauguration of the scheme in 1925 up to 583 (245 and 338).

Examinations were held in June and December of last year and a feature of the arrangements was that the examination on each occasion was conducted simultaneously at different places—Manchester, Glasgow, Nottingham, and Belfast. Seventeen candidates took the examination in June and 13 in December--the largest numbers yet recorded. For the year, there were 30 candidates, 19 of whom passed and thus completed qualification for the Associateship.

Annual Competitions: Woven Fabrics and Yarns

The Crompton Memorial Competition provides the most important section of the annual competitions of the Institute. Recent revision of the conditions relating to this competition (design and structure of woven fabrics) has aimed at securing a wider appeal to the advanced students at colleges or schools in the various textile centres. Although some response has been recorded as to increases of districts represented, yet there remains considerable room for expansion. It seems certain that if the terms and conditions of competitions existing to-day were more fully appreciated by both students and teachers a much wider representation would accrue. The numbers of competitors in the respective competitions for 1930 and 1929 were—(A) Competition (1930) 13 and (1929) 11; (B) 6 and 7; (C) 14 and 22; (D) 24 and 15. The total for all competitions reached 57 in 1930 against 55 in 1929. For the competitions additional to "A" (Crompton), the Institute has in past years received donations from generous supporters of the movement. It is sincerely hoped that further support may be forthcoming by way of donations in support of the special competitions. Mr. John Emsley, J.P. (Bradford), ex-President of the Institute, kindly attended and distributed last year's prizes to the successful competitors.

Scholarship Scheme

By means of funds available as a result of a donation of £5,000 from the Cotton Reconstruction Board and Cotton Trade War Memorial Fund, an Institute Scholarship has been inaugurated. The first award was made in the latter part of 1930 and Mr. Alan Ratcliffe, the holder, is pursuing a special course of studies at the Manchester College of Technology. It was hoped, at the outset, that the annual income available would provide for two scholarships running concurrently. This was not possible, but a second scholarship is to be offered, however, during 1931. The Scholarship is open to young craftsmen engaged in the cotton spinning or cotton weaving industry and presents opportunity to the young craftsman who would not otherwise be able to proceed in this direction.

Invested Funds

The total donation to the Foundation Fund of the Institute at the end of 1930 reached £19,020 11s. 6d. This amount includes £289 9s. 5d. profit on conversion of War Bonds. The amount also includes £861 9s. 6d. from the Institute Diplomas Account, £250 from relinquishment of former London office premises, £2,500 Crompton Memorial Fund (nominal value), and £5,000 donation from the Cotton Reconstruction Board and the Trustees of the Cotton Trade War Memorial Fund. The whole amount is invested with the exception of a small balance at bank of £4 16s. 6d. The interest from the Crompton Fund is applied to the Competitions Scheme, that from the London office tenancy surplus to the London Section, and that from the contribution from the Cotton Reconstruction Board and Cotton Trade War Memorial Fund is reserved for or applied to the Institute Scholarship Scheme which came into operation in the latter part of 1930.

Inquiries

Substantial service is provided to Members and others in the form of information in reply to inquiries. The Special Committee appointed last year by the Council gave special consideration to the methods of dealing with inquiries generally and a uniform system is now in operation with definite instructions as to inquiries according to their description.

Council and Committee Meetings

The following is the record of meetings held during the year (1st January to 31st December 1930)—Council, 11, Selection, 10, Publications, 11, Finance, 11; Propaganda, 5; Competitions, 2, Library, 4, Lancashire Section, 3, London, 5, Irish, 2; Yorkshire, 4; Scottish, 0; Midlands 4; Total 72, as against 78 in the previous year. In addition to the foregoing, nine sub-committees met for the consideration of special matters.

Section Meetings and Lectures

Six meetings of the Lancashire Section, and three joint meetings; two meetings of the Yorkshire Section, and two joint meetings; eight of the London Section, and two visits; three of the Irish Section, two of the Scottish Section and four visits; and two of the Midlands Section and two visits were held during 1930, at which papers were read and discussed.

Membership

The membership list at the end of 1930—to be carried forward to 1931—was made up as follows—Honorary Members 6, Life Members 30, Ordinary Members 1,324, Junior Members 116; total 1,542 as against 1,570 at the end of 1929. Of the Members at 31st December last, 157 had been admitted to the Fellowship and 196 to the Associateship.

The Council lament the loss by death during 1930 of F. J. Hoxie (U.S.A.); H. E. Aykroyd (Leeds); L. N. Dillon (S. America); F. C. Farrington (Manchester), H. Stott (Oldham); A. M. Wright (New Zealand); H. Lowe (France); J. J. Greenwood (St. Annes-on-Sea); James Bairstow (Keighley); C. E. Crowther (Manchester).

The death of Mr. Horace Lowe, the recipient of one of the first two Honorary Fellowships awarded by the Institute, is also deeply deplored.

In the early part of the present year, the death took place of Mr. E. B. Fry (London), who had been an active supporter of the Institute for many years. The demise of Mr. W. B. Richardson, of Farnworth, during April, is also to be recorded with regret.

BALANCE SHEET AND ACCOUNTS FOR 1930

The Hon. Treasurer (Mr. W. W. L. Lishman) reported on the finances and said that, although the Revenue Account showed a deficit, yet after careful consideration the Finance Committee concluded that the position was not unsatisfactory having regard to the prevailing conditions of general financial stringency. They looked to the members to use their influence in advancing the membership strength.

The Balance Sheet and Accounts, with the Auditors' Report, were received and accepted, on the motion of the Chairman, seconded by Mr. F. Nasmith, as follow—

Dr. The Textile Institute—Balance Sheet as at 31st December 1930 Cr.

LIABILITIES

1929 £ s. d.	LIABILITIES	£ s. d.	£ s. d.
140 10 0	Subscriptions paid in advance ...		155 18 6
	Life Membership Subscriptions Account—		
	Balance, as on 31st Dec. 1929 ...	59 15 7	
59 15 7	*Less* 10% transferred to Subscription Account	8 10 10	51 4 9
	Sundry Reserves, *viz.*—		
2500 0 0	Crompton Prize Fund	2500 0 0	
277 0 0	Life Membership Reserve Account	298 0 0	
97 10 0	Perpetual Membership ...	97 10 0	
10417 2 6	Foundation Fund	10417 2 6	
5000 0 0	Do. Cotton Reconstruction Board Grant	5000 0 0	
861 9 6	Do. Diplomas Account ...	861 9 6	
250 0 0	Do. London Section Reserve Account	250 0 0	19424 2 0
112 9 7½	Competitions Scheme—Income and Expenditure Account Balance		63 1 10
313 10 0	Scholarship Scheme—Reserve Account		441 7 4
75 0 0	*Journal* Account—Subscription from B.C.I.R.A. reserve ...	... ...	— — —
301 1 6	Sundry Creditors as per list ...		295 18 5
22 11 7	Bank Overdraft—General Account		166 2 1
52 6 9½	Revenue Account	.. .	— — —
£20480 7 1			£20597 14 11

NOTE—There is a contingent liability for Income Tax in respect of the years 1926-7 to 1929-30 inclusive, at present under appeal

ASSETS

1929 £ s. d.	ASSETS	£ s. d.	£ s. d.
	Cash at Bank—		
4 16 6	Foundation Fund Account ...		4 16 6
12 17 1	Cash in hand		8 16 2½
	Sundry Debtors—		
	Journal Account—		
326 8 3	Outstanding Advts. ...	223 9 6	
59 12 5	Outstanding Reprints ...	126 2 9	
— — —	Reprints reserved to 1931 ...	57 17 4	
	Outstanding Grant, Ring Yarn Association... ...	20 0 0	427 9 7
	Furniture, Fittings, and Library Account—		
	Balance as on 31st Dec. 1929..	632 17 3	
	Additions during Year ..	38 17 0	
		671 14 3	
632 17 3	*Less* Depreciation	88 14 10	582 19 5
	London Furniture Account—		
	Balance as on 31st Dec. 1929 .	41 17 0	
41 17 0	*Less* Depreciation	5 4 7	36 12 5
9 10 0	Gas and Electricity Deposits ...		9 10 0
	Investment Account (see Schedule)		
16515 14 0	Foundation Fund ...	16515 14 0	
2500 0 0	Crompton Prize Fund... ...	2500 0 0	
105 0 0	Life Membership Account ..	105 0 0	
97 10 0	Perpetual Membership Account ...	97 10 0	19218 4 0
174 4 7	Office and Rooms Alterations Account—Balance		130 13 5
	Revenue Account—Excess Expenditure over Income for Year ...	231 0 2	
— — —	*Less* Credit Balance on 31st Dec. 1929	52 6 9½	178 13 4½
£20480 7 1			£20597 14 11

AUDITORS' REPORT TO MEMBERS

We report to the members that we have examined the above Balance Sheet together with the books and vouchers of the Institute, and that we have obtained all the information and explanations we have required.

We further report that in our opinion the Balance Sheet is properly drawn up so as to exhibit a true and correct view of the Institute's affairs according to the best of our information, and the explanations given to us, and as shown by the books of the Institute

W. W. L. LISHMAN *Hon. Treasurer.*
FRANK NASMITH *Chairman of Council.*

27th March 1931
37 York Street Manchester.

(*Signed*) ARTHUR E. PIGGOTT, SON & SOUTHWORTH
Incorporated Accountants, Auditors.

Dr. The Textile Institute—Revenue Account for the Year ended 31st December 1930 Cr.

1929 £ s. d.	EXPENDITURE	£ s. d.	£ s. d.
	To Rent and Rates—Manchester ...	281 5 9	
152 5 3	*Less* to *Journal* Account ...	76 10 9	204 15 0
	,, Salaries	1313 16 0	
650 0 0	*Less* to *Journal* Account ...	663 16 0	650 0 0
	,, Wages	348 15 10	
255 5 5	*Less* to *Journal* Account ...	102 15 10	246 0 0
	,, Heating, Lighting and Cleaning...	97 17 4	
61 14 7	*Less* to *Journal* Account ...	32 12 5	65 4 11
	,, Offices, Canteen, and General Expenses, etc.		
80 2 8			103 4 6
37 10 8	,, Meetings Expenses	44 17 1	
20 18 7	,, Travelling Expenses	13 10 0	58 7 1
124 14 1	,, Postages, Telegrams, and Telephones		104 16 11½
163 9 10	,, General Printing and Stationery		117 19 8
5 9 6	,, Insurances		7 5 9
21 3 0	,, Audit and Legal Charges ...		23 5 0
5 5 0	,, Subscriptions to Institutions ...		5 5 0
23 16 0	,, Autumn Conference—Expenses, *less* Receipts		– – –
35 9 2	,, Library Account		104 0 11
	,, Section Expenses—		
278 1 1	London	221 14 7	
27 17 9	Lancashire	21 12 7	
30 8 1	Yorkshire	32 15 11½	
5 10 2	Scotland	9 17 8	
6 1 6	Ireland	12 9 5	
– – –	Midlands	13 11 7	312 1 9½
	,, Office Alterations—		
44 1 8	Amount written off		43 11 2
30 16 8	,, Diplomas Account: Expenses ...		47 9 5
– – –	,, Medal Account		8 0 0
– – –	,, Journal Account		97 15 8
– – –	,, Savings Association Contributions		16 16 0
103 8 11	,, Depreciation on Furniture ...		93 19 5
1 11 2	,, Bank Charges, *less* Interest ...		– – –
3 4 4	,, Exhibition Expenses, *less* Receipts		– – –
2168 5 1			2309 18 3
289 6 8	,, Excess Income over Expenditure		– – –
£2457 11 9			£2309 18 3

1929 £ s. d.	INCOME	£ s. d.	£ s. d.
	By Membership Subscriptions—		
	1262 Members at £2 2s. ...	2650 4 0	
	27 ,, £1 1s. (half-year)	28 7 0	
	90 Junior Members at £1 1s.	94 10 0	
	11 ,, ,, at 10s. 6d. (half-year)	5 15 6	
	Life Members—10% of Balance	8 10 10	
	Subscriptions in advance as per Balance Sheet, 31st Dec. 1929	140 10 0	
	Subscriptions in Arrear paid during 1930	43 12 7	
	Interest from Perpetual Membership, Life Membership, and Diploma Account Investments	52 5 10	
	Special Subscription—Weavers' Company	21 0 0	
	Diploma Fees	114 19 6	
		3159 15 3	
2171 18 8	*Less* amount transferred to *Journal* Account	1105 18 3	2053 17 0
20 0 0	,, Crompton Fund Administration Expenses		20 0 0
265 13 1	,, Foundation Fund—Income from Investments Account—Amount transferred		– – –
– – –	,, Bank Interest, *less* Charges ...		5 1 1
2457 11 9			2078 18 1
– – –	,, Excess Expenditure over Income		231 0 2
£2457 11 9			£2309 18 3

TOTAL ARREARS at 31st Dec. 1930		£307 14 0
ARREARS WRITTEN OFF	...	94 10 0
Total Arrears Current...	... ...	213 4 0

W. W. L. LISHMAN *Hon Treasurer.*

Audited and found correct,

Dr. The Textile Institute—Crompton Prize Fund Income and Expenditure Account for Year ended 31st December 1930 Cr.

1929 £ s. d.	EXPENDITURE	£ s. d.
64 18 0	To Printing and Stationery	57 15 11
92 17 4	,, Purchase of Specimens	40 15 9
8 2 6	,, Mounting of Specimens	9 2 6
123 9 8	,, Prize Awards and Expenses	146 15 6
4 14 10	,, Postages and Carriage	3 18 5½
20 0 0	,, Administration Expenses	20 0 0
314 2 4		278 8 1½
112 9 7½	,, Balance carried forward	63 1 10
£426 11 11½		£341 9 11½

1929 £ s. d.	INCOME		£ s. d.
169 4 11½	By Balance brought forward		112 9 7½
141 3 0	,, Albums Subscriptions		135 16 7
5 4 0	,, Competition Entrance Fees		7 15 0
50 0 0	,, Dividend on £1000 5% War Stock	50 0 0	
36 0 0	,, Dividend on £1125 4% L.M.S. Railway Stock...	35 8 9	85 8 9
25 0 0	,, Prize Money		— — —
£426 11 11½			£341 9 11½

Dr. The Textile Institute—Foundation Fund Income from Investment Account for Year ended 31st December 1930 Cr.

1930	EXPENDITURE	£ s. d.	£ s. d.
May 9	To Mather Lecture		25 0 0
Dec. 31	,, Interest on £844 9 2 5% War Stock (Diplomas) Transferred	42 4 6	
,, 31	,, Interest on £102 5 0 5% War Stock (Life Members) Transferred	5 2 3	
,, 31	,, Interest on £ 99 1 6 5% War Stock (Perpetual Members) Transferred ...	4 19 1	
,, 31	,, Interest on £240 0 0 5% War Stock (London Section) Transferred ...	12 0 0	
,, 31	,, Interest on £4870 0 0 5% War Stock (Scholarship) Transferred	243 10 0	
,, 31	,, Interest on £1000 0 0 5% War Stock (Crompton Fund) Transferred ...	50 0 0	
			357 15 10
,, 31	,, Journal Account		484 6 11
			£867 2 9

1930	INCOME	£ s. d.
Feb. 1	By Dividend £1242 10s. 4% Consolidated Stock *less* Tax	19 17 8
May 1	,, ,, £1000 4% Funding Loan 1960-1990 *less* Tax	15 10 0
June 1	,, ,, £15939 18s. 10d. 5% War Stock 1929-1947	398 9 11
Aug. 1	,, ,, £1242 10s. 4% Consolidated Stock *less* Tax	19 5 3
Nov. 1	,, ,, £1000 4% Funding Loan 1960-1990 *less* Tax	15 10 0
Dec. 1	,, ,, £15939 18s. 10d. 5% War Stock 1929-1947	398 9 11
		£867 2 9

W. W. L. LISHMAN *Hon. Treasurer.*
FRANK NASMITH *Chairman of Council.*

Audited and found correct,
27th March 1931
37 York Street Manchester.

ARTHUR E. PIGGOTT, SON & SOUTHWORTH
Incorporated Accountants, Auditors.

Dr. The Textile Institute—Journal Account for the Year ended 31st December 1930 Cr.

EXPENDITURE

1929 £	s.	d.		£	s.	d.
2906	5	5	To Printing, Reprints, and Postages (Distribution)	3213	4	11
64	4	5	,, Literary Contributions and Abstracts	27	11	1
609	18	0	,, Salaries ...	663	16	0
75	1	8	,, Wages (*less* £20 Ring Yarn Association)	82	15	10
65	0	1	,, Postages, Telegrams and Telephones...	52	17	6
91	14	11	,, Stationery, Binding, and *Journals* purchased	45	5	8
56	2	0	,, Advertisement Commission ...	56	4	3
7	5	0	,, Travelling Expenses ...	20	14	9
76	2	7	,, Rent and Rates (Proportion) ...	76	10	9
30	17	4	,, Heating, Lighting, and Cleaning (Proportion)	32	12	5
75	0	0	,, Reserve—Subscription from B.C.I.R.A. carried forward	–	–	–
£4057	11	5		£4271	13	2

INCOME

1929 £	s.	d.		£	s.	d.
75	0	0	By Reserve—Subscription from B.C.I.R.A., brought forward ...	75	0	0
			,, Grants—			
150	0	0	British Cotton Industry Research Association	–	–	–
100	0	0	Linen Industry Research Association ...	81	17	6
10	10	0	,, Subscription from Clothworkers' Company ...	10	10	0
1749	6	8	,, Advertisements and *Journal* Subscriptions ...	1615	19	9
663	1	0	,, Reprints ...	800	5	1
1089	7	6	,, Transfer from Membership Subscriptions ...	1105	18	3
220	6	3	,, Transfer from Foundation Fund Income from Investments Account ...	484	6	11
–	–	–	,, Revenue Account ...	97	15	8
£4057	11	5		£4271	13	2

Schedule of Investments (at Cost or Value at original date of gift) as on 31st December 1930

					£	s.	d.	£	s.	d.
Foundation Fund—										
£8784 3 2	£3737	14	9	5% War Stock 1929-47	3503	7	0			
	£4789	9	5	5% War Stock 1929-47	4789	9	5			
	£ 48	16	3	5% War Stock 1929-47	49	14	1			
	£ 105	5	3	5% War Stock 1929-47	106	14	0			
	£ 102	17	6	5% War Stock 1929-47						
£5212 17 6	£4870	0	0	5% War Stock 1929-47 (Scholarship Scheme)	5355	0	0			
	£ 240	0	0	5% War Stock 1929-47 (London Section)						
	£ 650	0	0	5% War Stock 1929-47 (Diplomas) ...	661	9	6			
	£ 194	9	2	5% War Stock 1929-47 (Diplomas) ...	200	0	0			
	£1000	0	0	4% Funding Loan 1960-90	800	0	0			
	£1242	10	0	4% Consolidated Stock	1050	0	0	16515	14	0

					£	s.	d.	£	s.	d.
Brought forward ...								16515	14	0
Crompton Prize Fund—										
	£1000	0	0	5% War Stock 1929-47	1000	0	0			
	£1125	0	0	4% L.M.S. Railway Preference Stock ...	1500	0	0	2500	0	0
Life Membership Account										
	£52	5	0	5% War Stock 1929-47	53	14	6			
	£50	0	0	5% War Stock 1929-47	51	5	6	105	0	0
Perpetual Membership Account—										
	£99	1	6	5% War Stock 1929-47				97	10	0
								£19218	4	0

W. W. L. LISHMAN *Hon. Treasurer.*
FRANK NASMITH *Chairman of Council.*

Audited and found correct,
27th March 1931 37 York Street Manchester. ARTHUR E. PIGGOTT, SON & SOUTHWORTH *Incorporated Accountants, Auditors.*

ELECTION OF PRESIDENT

The Chairman next proposed the election of Mr. George Garnett, J.P., of Bradford, as President for the ensuing year, and in doing so said it was most desirable that the distinction should from time to time become associated with the districts connected with the various Sections of the Institute. He was quite certain that Mr. Garnett would prove a most capable President. The Institute continued to grow steadily, and the fact should not be lost sight of that the foreign membership had considerably increased in late years. The Diplomas of the Institute gave a recognised standing to the successful applicants and there seemed every reason to suppose that the scheme of professional qualification in textile technology would be carried forward with increasing success.

Mr. F. Nasmith (Chairman of Council) seconded the proposal, and said that in view of the enormous amount of work which Mr. Garnett contributed to the Institute movement in its early days, it was most fitting that he should now be elected to the highest office.

The motion was carried unanimously, and Lieut.-Col. Dobson then invested the newly-elected President with the Institute's presidential badge.

Accepting the presidency, Mr. Garnett said— The very fitting celebrations of the Coming-of-Age of this Institute, a fortnight ago, have effectively brought before the commercial community of this great country the activities of an institution of supreme value; created by men of talent, personality, and leadership, who have given freely of their time, ability, and means, to raise the status of the textile trades and the welfare of hundreds of thousands of those engaged in it. In this connection the word "welfare" stands in its larger setting, as it covers the full meaning of a successful career industrially and nationally.

A review of the chronology of its twenty-one years' life issued at the celebrations shows the romance of its growth, and what features from time to time gave it a new impetus. The institution of the Mather Lecture; the creation of the Foundation Fund by the late Sir Frank Warner in 1918, Mr. John Crompton's munificent gift of the Lieutenant Crompton Memorial Prize Fund for competitions in design and structure of woven fabrics in 1922; and the granting of the Royal Charter in which Mr. Emsley gave such valuable service, deserve special mention.

What to-day, therefore, is its special appeal to the textile industries—what its contribution ?

Firstly- It can and must be one of the main platforms for statements of outstanding value on subjects directly or indirectly affecting our industrial destiny, foreign relationships, economics, scientific research, education, psychology of control, etc. Other bodies have greater facilities for specific work in these matters than we have, but they are none the less of vital moment to us, and our Institute must ever be worthy of being the platform for opportune announcements and discussions. Some of the causes of the present paralysing world depression could most usefully be discussed. Last December the Council of the International Chamber of Commerce suggested to its various National Committees, the following as among the chief causes—

(1) A general increase in productive capacity which has temporarily outstripped the rate of increase in population and in the capacity of consumption,

(2) Following upon a long period decline in world commodity prices, a further sharp and excessive fall in prices, especially in raw materials and foodstuffs, not only too rapid but also too extensive to enable cost of production to be adapted and throwing retail prices out of equilibrium to wholesale prices. Immediate recovery from the prevailing price depression is delayed by the postponement of liquidation in stocks;

(3) The world-wide agricultural crisis;

(4) The unprecedented extent of industrial unemployment;

(5) The prolonged malaise caused by political unrest;

(6) The closing partial or complete of some of the world's most important markets;

(7) The slow readjustment of national to the international economic situations by reason of the various bases chosen for monetary stabilisation;

(8) Barriers to enterprise and investment imposed in many places by an unusual spread between long and short term money rates;

(9) The heavy fall in the price of silver which has further reduced the purchasing power of one-third of the world's population;

(10) The forcing on the world's markets of large quantities of grain, raw materials, and semi-finished products by Soviet Russia at prices less than the normal cost of production;

(11) The levying in many countries of heavy taxation, in order to meet unprecedented national and international indebtedness;

(12) Excessive incursions of the State into the domain of private enterprise (which are clearly hindering and in some cases actually preventing the necessary accumulation of private capital, and the inducements to private enterprise and venture)

MR GEORGE GARNETT, J.P., F.T.I.
(*President of the Textile Institute*)

Since the war there has grown up abroad a spirit of nationalism and self-containment which may have temporary advantages but which means extensive duplication of plant and serious disturbance of our international trade. We must naturally view with a good deal of alarm the establishment of secondary industries in the Dominions of Canada and Australia, unless the economic balance of trade and the increased wealth of the world create corresponding expansion in the consumption of textiles—which cannot take place before the birth of another generation. The world depression through which we are now passing is exercising the finest minds in all countries. As a leading article in last week's issue of the *Economist* reads—

"The biennial meeting of the International Chamber of Commerce at Washington a fortnight ago is a striking illustration of this; the report of the week's proceedings provide abundant food for thought to the rulers and business men of the United

States and of Europe, not because any diagnoses or remedies for the current malady were forthcoming, but because the general effect of the discussions was to leave three great problems standing out clearly as transcending all others, namely, disarmament, tariffs, and international debts. Once again the captains of industry of every country have pointed out to the Government and the peoples the only road that leads to economic salvation. They have heard once more reiterated, emphasised, underlined, the immutable truth of economic law which briefly stated is, that in proportion as the free flow of commerce is blocked the production of the nations will be restricted and the recovery of their prosperity effectively impeded, and the peace of the world jeopardised by the strain of economic warfare."

These decisions are in other hands than ours, and we must content ourselves with the education of our members to deal with such changes as this new situation is bringing about.

Secondly—Commercialised art—to use a term I have recently seen, which is more descriptive than euphonious, must receive greater emphasis from us. In the onward march of civilisation, power and purpose may fully reach their goal without much embellishment of their outer coverings; an express service locomotive is a business proposition according to its efficiency and not according to the colour it is painted; a card, a spinning frame, or a loom, is purchased for its quality and quantity production, and not for any value attached to chromium plated parts or a painted framework; but, when we come to fabrics, art plays as great a part in its final acceptance as its technical construction. We take no second place in the building of fabrics for every conceivable purpose of wear and household decoration; our textile industries pioneered the development in every other country, and by our perfection of our machines we have created competition of no mean order in our foreign markets. In the matter of men's wear goods, all the world comes to London for its choicest selections. It is the centre where every season, colour, decoration, and finish stimulate the textile trade at home and abroad, and it has brought us an unrivalled position in initiative and production; the genius is native to us, it only needs research and persistent cultivation in the new generation to enable us to retain our hold. As to the women's trade, though the Wembley Exhibition did not seem to leave any tangible results, later endeavours and organisation of this section of the trade have certainly created in London a more influential fashion centre—a public acknowledgment of the beauty and intrinsic worth of British fabrics shown from season to season. Here again have we seen a distinct advance in the association of art with technology expressed in ways little thought of as possible a few years back. As Paris still holds the lead for this trade, English manufacturers must be prepared to spend more money in the education of their designers and to sample this market much more extensively, and I am sure the labour will bring its reward. All these designers should be our special care and responsibility, and I think that the Institute should take up the question of the application of colour to fabrics as a new study capable of extensive research and development.

This should supplement what our Technical Colleges and Schools are already doing, which I feel is excellent as far as it goes; as our Research Associations on the scientific side have become an indispensible part of the development of our industries, and have proved their value in a thousand and one ways, so I believe the mental training of our designers can be very considerably stimulated by more definite study than earlier opportunities afforded them. Fine colourists to-day are an asset to any manufacturer. With some it is a natural expression of native genius; others, under the stimulus of a sympathetic atmosphere or teacher, would soon show marked advance over previous work. They should be sent away periodically to centres that are influences of fashion and good taste in dress. In this way I would raise the status of our textile production and hold the field with superior productions in any type of fabric.

In the manufacture of staple lines, the position is different. Here it is more a matter of factory organisation, of skill in management, of lower unit cost in

production, of definite whole-hearted co-operation to get the best results at the lowest possible price. Our Associateships, leading up to Fellowships, will provide the new men for these positions. This is their ambition as well as ours, and as thoroughness and qualification are the guiding principles of the Selection Committee, these men should be a credit to the Institute as well as themselves, and should be sought for in the coming changes.

Lastly—I should like to refer briefly to the reports of the Trade Missions that have recently returned from foreign fields. The Scotch delegation to the Continent discovered much piracy of designs and colours—dishonest, but a great compliment to our unique position—marked advancement in production of goods, both cheap and good; that Continentals work harder and longer to recover and extend their former position and are succeeding in doing so, that fashion-intelligence services had been established in Paris that we had never dreamt of in this country, again proving the new emphasis in art in industry. In the Far East the new economic and industrial position, and the seriousness of the new competition that was arising out of it, dominated the report. We are losing these markets because of the high price of our goods. The technical features which more directly concern us suggest newer yarns and fabrics that must be created if we are to get a semblance of the trade that is still possible to us—again a matter of commercialised art. We have also the words of our illustrious Royal Trade Missionary, the Prince of Wales, who was accorded such a worthy reception in Manchester last week. In a speech packed with shrewd observation and constructive suggestion, he said that we should sacrifice some of the high finish and solidarity of our manufactures to bring them nearer to the competitive price. Make goods South America wants and which our rivals are providing, brighter in appearance. This certainly will not be English standard practice, but the distresses of the times demand that we should fit the pockets of the people by providing copies as well as originals of high quality goods. Again I notice that goods must be more colourful.

If the new generation of members of the Institute endeavour to realise the enormous amount of self-sacrifice, ability, and labour that has been given in the past, and still being given to-day, by men of outstanding merit and leadership, for the benefit of industry through this Institute, I am confident that its prestige will not wane but its value and service will be sought by an increasing army of men bent on maintaining the premier position, and saying, in the words of the Prince last week, "In the struggle that lies ahead, you can always count on me."

Mr. Garnett next moved a vote of thanks to Lieut.-Col. Dobson, Past-President, who had, he said, during the past two years, contributed excellent service and maintained the prestige of the organisation. He hoped and believed that although Col. Dobson was leaving the chair they would have the benefit of his interest and support for many years to come.

Mr. W. Frost seconded, and said that the retiring President had shown marked ability and had exceptional qualifications for the office.

The motion was carried by acclamation, and Lieut.-Col. Dobson, in reply, said he would certainly continue to be warmly interested in the welfare of the Institute. He would look back upon the meetings of Council and Committees which he had attended, and was sure he could regard them as marking some of the best days in his experience of organised effort.

Moved by Mr. Frank Wright, seconded by Mr. C. Hutton, three vacancies in the list of Vice-Presidents were dealt with by re-election and election as follow—Messrs. A. F. Barker and W. Frost, re-elected; Mr. E. Midgley, elected.

The result of the ballot for the election of ten members of Council was announced as follows—*Elected:* W. Wilkinson (Blackburn); H. Nisbet (Manchester); W. Davis (Nottingham); F. Wright (Bolton); W. W. L. Lishman (Todmorden); H. C. Barnes (Manchester); G. A. Barnes (Bolton); T. Woodhouse (Blackpool); A. W. Stevenson (Galashiels); J. H. Strong (Great Harwood).

The Institute's Auditors (Messrs. A. E. Piggott, Son & Southworth Ltd.) were re-elected on the motion of Mr. Lishman, seconded by Mr. Nasmith, and the proceedings then terminated.

LONDON SECTION ANNUAL MEETING

The ninth Annual Meeting of members of the London Section was held at 104 Newgate Street, London, E.C.1, on Thursday, 7th May 1931. Mr. F. Henley presided, and there were also present Messrs. W. N. Bacon, A. Farmer, A. E. Garrett, A. Gowie, J. Howard, W. Jaffe, A. Mason, W. Matthews, R. S. Meredith, T. C. Petrie, G. A. Rushton, S. A. Williams, E. Wigglesworth, and A. R. Down (Hon. Secretary). Apologies for absence were received from Messrs. A. B. Ball, H. J. Clarke, C. H. Colton, H. B. Heylin, L. J. Mills, R. J Peers, and W. C. Whittaker.

The minutes of the previous Annual Meeting (15/4/1930) were read and approved.

Annual Report—This report of the Committee was read and approved. The report reviewed the work of the past year and stated that since the last annual meeting the London Section had lost through resignations, transferences, and other causes, a total of 98 members. This decrease was mainly due to the formation of the new Midlands Section, to which 77 of the members had been transferred. During the year 20 members had been added, and the total membership of the Section was now 155. It was with deep regret that the death of Mr. E. B. Fry, a Vice-Chairman, was recorded. Mr. Fry was a Founder member and a member of the Council, rendering valuable service to the Institute and to the London Section in particular.

Owing to the splitting off of the Midlands manufacturing members, the scope of the London Section remained purely distributive and educational. Various difficulties arose from this situation which were receiving the earnest consideration of the Committee.

There were now 13 members of the Section holding the Fellowship, one the Honorary Fellowship, and eight the Associateship.

During the Session 1930–31, four public lectures took place, one by the kind permission of the Clothworkers' Company in their Hall, and others in the Hall of the L.C.C. Barrett Street Trade School. Last year's Committee recommended that the holding of lectures in the West-End of London be extended, and this departure proved very popular. In addition to the public lectures, four informal discussion meetings have been held in the Members' Room at the Offices of the Section. The total attendances constituted a record, and the programme had proved most successful in every way.

At the kind invitation of Messrs. Bentley Ltd., a number of Section members visited their laundry on 15th October 1930. After inspecting the processes and works, the members were entertained to tea. On 15th March 1931, by the courtesy of Messrs. British Ropes Ltd., a party visited the works, and the event proved successful and interesting. Tea was kindly provided. On Saturday, 24th January 1931, a number of members visited the Exhibition of the Linen Industry Research Association at the National Science Museum, South Kensington, S.W. The party was conducted by Captain Evans, who explained the exhibits, which illustrated the extent of the valuable work being carried out by the Association.

The arrangement with the British Institute of Industrial Art for office accommodation terminated on 31st December 1930. The Committee regret losing these friends, but owing to reorganisation of the Institute the change was inevitable.

Arrangements for parties of London students to visit Lancashire mills in the near future are in course of preparation. This development is receiving the cordial support of Council.

In the interests of economy, after consultation with the Council, arrangements were completed (as from 25th March 1931) by the courtesy of the Drapers' Chamber of Trade of the United Kingdom, whereby separate clerical assistance for the Section could be dispensed with, the direction of affairs, of course, remaining under the control of the Honorary Secretary, Mr. A. R. Down. The Committee wish to place on record their appreciation of Miss Flitton's services to the Section during the past seven years.

The Committee were unanimous in recording their grateful thanks to their Chairman (Mr. F. Henley) and Honorary Secretary (Mr. A. R. Down), for their continued great interest in the Institute, and for their valuable work during the year under review.

Nomination of Committee—The Hon Secretary reported that 20 nominations had been received and that no postal ballot was therefore necessary. The nominations received were—Messrs. A. B. Ball (Silk Association of Great Britain and Ireland, Inc.), H. J. Clarke (Selfridge & Co. Ltd.), C. H. Colton (British Celanese Ltd.), A. R. Down (Antony Gibbs & Sons), A. E. Garrett (The Jaeger Co. Ltd.), A. Gowie (The Drapers' Chamber of Trade of the United Kingdom), F. Henley (Liberty Ltd.), H. B. Heylin (War Office, Army Ordnance Service), J. Howard (Office of the High Commissioner for India), C. W. James (Imperial Chemical Industries Ltd.), A. Mason, W. H. Matthews (Board of Trade), R. S Meredith (Adam & Lane & Neeve Ltd.), L. J. Mills (International Correspondence Schools), P. J. Neate (Worshipful Company of Clothworkers), J. R. Peers (National Federation of Launderers Ltd.), G. A. Rushton (Office of the High Commissioner for India), E. Wigglesworth (Flax Tow Manufacturers Ltd.), S. A. William (London County Council), W. C. Whittaker (Harrods Ltd.).

The meeting decided that the foregoing nominations should be recommended to Council for election.

Chairman, Vice-Chairmen, and Officers It was the unanimous wish of the meeting that Mr. Henley should again be nominated as Chairman. Many members referred to the excellent work Mr. Henley had done during the past years, and suggested that it would be in the best interests of all if he would consent to carry on for another year while the reorganisation of the Section was in progress. Mr. Henley consented to accept nomination.

The following were nominated Vice-Chairmen- Messrs. A. E. Garrett, J. Howard, P. J. Neate, and E. Wigglesworth. Hon. Secretary--Mr. A. R. Down.

Mr. G. A. Rushton proposed that, in view of the new arrangements whereby there would be a closer working arrangement in clerical matters with the Drapers' Chamber of Trade, Mr. Gowie should be nominated as Hon. Assistant Secretary. The meeting accepted Mr. Rushton's suggestion, and Mr. Gowie consented.

The Chairman and Hon. Secretary referred to the very sincere and able manner in which Mr. Rushton had served the Section in the past, and it was unanimously decided that a record of the Section's appreciation of Mr. Rushton's services should be recorded on the minutes.

Premises and Arrangements The Chairman outlined the new arrangements as to the London premises, which the meeting accepted as being very satisfactory. A vote of thanks was given to Mr. A. Gowie for his efforts, which had brought about this solution of the Section's difficulties.

It was decided that a small token should be given to Miss Flitton as a mark of appreciation of the manner in which she had carried out her duties. The arrangements for this were left in the hands of Messrs. F. Henley and A. R. Down.

Votes of Thanks— Hearty votes of thanks were accorded to the Worshipful Company of Clothworkers and the Drapers' Chamber of the United Kingdom, for the great assistance and considerable services they had given, and the meeting closed with a warm vote of thanks to the Chairman.

MIDLANDS SECTION ANNUAL MEETING

The first annual meeting of the Midlands Section of the Institute was held at the University College (Shakespeare Street), Nottingham, on the afternoon of Saturday, 16th May 1931, under the chairmanship of Mr. T. Morley, of Leicester, when there was an attendance of about 25 members.

The Hon. Secretary (Mr. J. Chamberlain) submitted a report which reviewed the meetings of the past year. So far, a Provisional Committee had served the Section and the attendance records as to committee meetings were presented. Thirteen new members had joined since the Section was formed, bringing the total to 101. The general meetings and visits to works had secured an average attendance of about 30 members.

Nominations were invited for membership of Committee for the coming year and it was agreed that the following be recommended to Council for election—Messrs. H. S. Bell (Mansfield), P. A. Bentley (Leicester), W. N. Bignall (Nottingham), J. Chamberlain (Leicester), H. F. Lilburn (Leicester), T. Morley (Leicester), S. A. Simpson (Loughborough), A. Stoppard (Nottingham), E. Walker (Nottingham), S. E. Ward (Nottingham), E. Wildt (Leicester).

The matter of Section meetings to be arranged for next session was discussed and it was agreed that the Committee should consider meetings for Nottingham, Leicester, and Hinckley, and possibly Derby. It was also agreed that the Committee should consider inclusion of a social event in the programme and one or two further visits to works. It was also agreed that arrangement of meetings jointly with other bodies be considered.

Mr. J. H. Lester, M.Sc. (Manchester), was next called upon to give an address on "The Past, Present, and Future of the Textile Institute." Mr. Lester dealt particularly with the Institute's scheme of professional qualification of members. The progress of the Institute had been most satisfactory in many respects and its standing would be exactly what it deserved to be according to the efforts and contributions of its individual members. In the near future, the Institute should play a leading part in influencing educational methods, whether in the interest of the manual textile worker, of the budding graduate, or of the academically trained man seeking to gain a footing in industrial work. The opportunity offered by the Institute to Members, Associates, and Fellows to read papers for publication in the *Journal* was strongly advocated as a means whereby a man's capabilities could be made known to his technical and scientific brethren. It was by such means that the status of the *Journal* and of the Institute could be best raised in the public estimation. The interests of design and of art were already encouraged through the Crompton Scheme, but he (Mr. Lester) stressed what he considered to be even more important- knowledge of the "art of textile manufacture" in the sense of acquaintance with the methods, operations, and processes involved.

On the motion of the Chairman, seconded by Mr. S. E. Ward, a hearty vote of thanks was accorded Mr. Lester. Mr. Ward said that after listening to the address many members of the Section would be better able to appreciate the value of the work of the Institute. He would like to stress the usefulness of the Institute as an exchange of opinion on technical matters. A great deal could be done by helping one another.

On the motion of Mr. Bentley, the Chairman was heartily thanked for his services and the proceedings concluded with tea by the kind invitation of Mr. Ward.

REVIEWS

Elementary Textile Microscopy. By John H. Skinkle. (Published by the Howes Publishing Co., New York. (144 pp., 95 figures.)

The purpose of this book is stated in the preface to be ". . . a combination text and laboratory manual for the author's classes in Microscopy at the Lowell Textile Institute, but it is also intended to be of aid to the independent worker in the industry . . . ." Undoubtedly a book that fulfilled these requirements would be extremely valuable, since there is at present no book in the English language which does so.

The photomicrographs do not set a good example to the beginner, since several of them appear to be out of focus and to have been given incorrect exposures, in spite, or perhaps because, of the author's cumbersome formula for calculating exposures which is given on p. 97. Though this formula involves seven factors, yet it does not exhaust the variables occurring in photomicroscopy, while definitely misleading data on the speeds of different plates is included. Actually the only entirely satisfactory method of gauging exposure is to take a trial exposure for each different preparation and optical arrangement, though fairly good results can be obtained, when using white light, by the aid of an actinometer.

Both fibres and starches are easy microscopical objects to photograph for their main morphological characteristics; it is therefore surprising that the photomicrographs of many of these are so indistinct. The cross-sections of fibres illustrated are slightly better, though they are all of rayons and all appear to have been produced by the author's so-called "rayon condenser." This method of section cutting is identical in principle with that of A. Wöllhaf, *Kunstseide*, **12**, 422, 1930. It is extremely convenient for the identification of fibres, yet it does not show up the finer details, nor does it permit of the examination of dark-coloured fibres. It would, therefore, have been useful to give illustrations of the results of other methods also.

No details of the methods of illuminating fabrics for examination under low powers is given in the twelve pages devoted to this subject, while Fig. 79, of cloth before and after schreinering, is unintelligible even with an *a priori* knowledge of this process and the appearance it produces. There is, of course, no difficulty in photographing the effects of this process (*Textile Manufacturer*, LVI, 284, 1930), provided the principles of the method are understood. Equally sketchy is the treatment of dark ground illumination and polarised light methods, pp. 106-7, yet the student is told in Experiment 23 to take photographs of fibres by these two methods. It is unquestionable that a student with no more information than has been obtained from this book would neither be able to take these photographs himself, nor understand them if he did.

It appears that the author has applied the Monroe doctrine to his search of the literature, for of the few references quoted at the end of the book, no mention is made of the many valuable papers that have been appearing in the English and German literature. This is a pity, for even a reference to where these are to be found would be extremely useful to students. Also the valuable books of A. Herzog and Ambronn-Frey are not mentioned in his bibliography.

If a later edition is published, it is to be hoped that the author will give simple working instructions for the carrying out of the various microscopic manipulations which are omitted here. For the conception and general design of the book are good, and it is therefore the more unfortunate that it should have been spoilt by bad detail work. J.M.P.

Textile Design and Colour: Elementary Weaves and Figured Fabrics. Third Edition; with Appendices on the Manufacture of Rayon (Artificial Silk) and Standard Yarns, Weaves, and Fabrics. By William Watson, F.T.I. Published by Messrs. Longmans, Green & Co. Ltd. (476 pages; 438 illustrations; 8vo; price 21s. nett).

A text-book on a subject relating to any section of an important industry or trade and which is fortunate enough to survive the critical test of two editions and enter on a third, requires no introduction, and becomes its own testimonial The volume under review has emerged successfully from this test, and it is sure to be welcomed, especially by students of the principles and fundamental structures of woven design and their practical application in the construction of the

elementary types and varieties of textile fabrics produced from any of the textile materials comprising cotton, linen, wool, silk, and rayon.

The author treats the subject of textile design and fabric structure in the manner appropriate to the specific purpose of a text-book for students, that is, in the natural progressive sequence from the simplest and most elementary weave structures, and leading step by step to the more advanced and complex. By this method the student acquires a clear and logical conception of the fundamental principles on which the various weave structures are based, and of their suitability for the creation of the various textural features according to the different purposes for which the fabrics are intended.

Further, the subject of textile design is, wisely, treated from the structural as well as the decorative and æsthetic points of view; this being highly desirable for the designer. Not only are the simple tappet and dobby structures dealt with, but also the method of preparing Jacquard designs is fully described, as well as the principles of colour and their application to textile fabrics of all types from the simplest weave structures to the more elaborate decoration of Jacquard figured fabrics.

The practical utility of this text-book is still further enhanced by two useful appendices. Appendix 1, which was also a feature of the second edition, is devoted to three glossaries of standard yarns; standard weaves; and standard fabrics respectively. Appendix 2 is additional to this edition and gives a very condensed treatise on the manufacture of rayon of the various types.

As an appendix, this section may prove a useful supplement to the book as a general treatise for the student of general textile technology, and this is probably the aim of the author. To those in possession of either of the previous editions of this work, this appendix would not justify the cost of the third edition. As a really useful text-book on the principles of woven design, the present volume can be highly recommended to students. The book is provided with an excellent index with cross references. H.N.

Cotton Doubling and Twisting. By Sam Wakefield Published by C. Nicholls and Co. Ltd., Manchester.

This is the second edition of a very well-known work in four volumes first published in book form in 1915. The comment by the author, in his preface to the first edition, on the paucity of published matter relating to the processes involved in cotton doubling is still largely true, and as copies of the former edition have for long been difficult to obtain, the issue of the second edition will be generally welcomed. The work is a comprehensive one, and gives a very good general description of the machinery, appliances, and methods employed in that large and increasingly important branch of the cotton trade which is responsible for the production of almost all the varied types of doubled yarn required by the manufacturer and finisher.

In the present edition a good deal of remodelling and amplification of the original matter has occurred. To bring the work more up to date, considerable additional matter has been introduced, amongst which reference is made to important recent developments in the process of gassing, the driving of twisting spindles, and winding and beaming methods. The work retains its previous form, each of the four volumes comprising two sections. The subject matter, which is amply illustrated, is well arranged and dealt with in a clear and concise manner, and each section is adequately indexed.

Volume I. Section I- Yarn testing and sampling. Section II—Double winding.

Volume II. Section III—Flyer and ring twisting. Section IV—Twiner twisting.

Volume III. Section V—Clearing and gassing. Section VI—Reeling, preparing, and making-up.

Volume IV. Section VII—Threads and their manufacture. Section VIII—Costs, waste, and organisation.

The author, who has long been recognised as an authority on matter relating to practical cotton doubling, can be congratulated on a work which has been of considerable service, not only to those specially concerned with practical cotton doubling, but to textile students generally. The additions which have been made to the present edition, give added value to a work which can be recommended as a treatise on the general processes involved in cotton doubling. C.B.

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PROCEEDINGS

Examination in General Textile Technology

An examination in General Textile Technology in connection with applications for the Associateship of the Textile Institute took place at Headquarters, Manchester, and simultaneously at the Municipal College of Technology, Belfast, and the Royal Technical College, Glasgow, on Wednesday, 17th June 1931 For the information of members and others interested, the examination paper, in two parts, is recorded as follows

PART I (SECTIONS I AND V OF SYLLABUS)

10 *a m to* 1 *p m.* 17*th June* 1931

Candidates to answer THREE out of FOUR Questions in each Section of Part 1

Section I—Fibres, and their Production

(1) What is a bast fibre? Indicate diagrammatically that part of the plant from which the fibrous layer is obtained, and describe the method of abstracting the fibre in the case of any one commercial variety.

(2) What are the factors which determine the equilibrium amount of water absorbed by textile fibres from the air? Describe in detail how changes in the magnitude of these factors affect the amount of water absorbed and place the following fibres in order of their affinity for water cotton, wool, silk, and acetate artificial-silk.

(3) Describe the physical properties which make the following fibres suitable for the purposes named—

(*a*) Silk for the manufacture of parachute fabric.

(*b*) Linen for (1) aeroplane wing fabric, (2) tropical suitings.

(*c*) Wool for (1) blankets, (2) outer-wear clothing materials.

(*d*) Cotton for (1) tyre cords, (2) absorbent cotton-wool.

(4) Discuss the advantages and disadvantages of Rayon as a textile material

Section V—Analysis and Testing of Raw Materials, Yarns, and Fabrics

(1) In what way do the following factors influence the apparent strength of yarn— (*a*) rate of loading, (*b*) length of test piece, (*c*) moisture content? The type of yarn to which reference is made should be specified.

(2) Describe a method of determining the Mean, and a measure of the Variability, of a large number of individual test results.

(3) State the foreign materials (including adulterants or accidental impurities) which you would expect to find in the following—(*a*) low quality calico, (*b*) a heavy crepe-de-chine fabric, (*c*) fire hose which has rotted in use, (*d*) white cotton fabric which has yellowed on storage, (*e*) non-inflammable flannelette.

(4) How would you make a quantitative analysis of a wool and cotton mixture fabric ?

PART 2 (SECTIONS II, III, AND IV OF SYLLABUS)

2.30 *p.m. to* 5.30 *p.m.*—17*th June* 1931

Candidates to answer TWO out of THREE Questions in each Section of Part 2

Section II—Conversion of Fibres into Finished Yarns

(1) Compare the processes of preparing and spinning in one of the following cases—(*a*) linen yarn on the line and tow systems, (*b*) thrown and spun silk, (*c*) woollen and worsted. Discuss the effects of the material and processes on the properties of the yarns produced.

(2) What is the object of varying twist in yarns ? Which textile fibres do you associate with low twist yarns and which with high twist yarns, and why ? What are the uses and disadvantages of high twist ?

(3) Outline briefly the various methods of yarn spinning and compare the types of yarn produced.

Section III—Conversion of Yarns into Fabrics, and Fabrics produced by Special Methods

(1) What is there to be said for and against the adoption of automatic looms in place of non-automatic looms ? Discuss the question from the point of view of (*a*) economy of productive costs, (*b*) relative quality of cloth, (*c*) capacities of change of weave to suit variety of design, colour, and interweave.

(2) Compare the properties of woven, knitted, and warp-loom knitted fabrics.

(3) How is the warp held in tension during the process of weaving ? Make a simple sketch to show the arrangement of mechanism provided on (*a*) a hand loom, (*b*) a power loom, and (*c*) a power loom with automatic let-off motion.

Section IV—Conversion of Fabrics into Finished Materials

(1) Describe the behaviour of each of the following fibres towards acid, basic, and direct dyestuffs—(*a*) cotton, (*b*) viscose rayon, (*c*) acetate rayon, (*d*) wool, and (*e*) natural silk.

(2) Wool and cotton react differently with acids and with caustic alkalis. Discuss the action of each reagent on both fibres and outline a process in which use is made of their different reactivities towards one of these reagents.

(3) Explain why the milling process can be applied only to fabrics composed wholly or partially of animal fibres such as wool. Discuss the nature of milling shrinkage and describe a method for treating fibres so as to prevent it.

Yorkshire Section

Joint Meeting with the Keighley Textile Society, 9th March 1931.
Chairman, Mr. H. B. Cordingley.

EVOLUTION OF FASHION AND ITS EFFECT ON FABRICS

This lantern-illustrated lecture was delivered by Mr. A. M. Chapman (Fellow) to a joint meeting of members of the Institute and of the Keighley Textile Society; ladies were specially invited. After an introduction in which some of the vagaries of fashion such as the crinoline, hobble-skirt, and bustle were referred to; the lecturer attempted an analysis of the causes of changes in fashion. We have adapted our dress, said Mr. Chapman, to the conditions under which we live. Woman, consciously or unconsciously has recorded history in her dress. After the French revolution women's dress reflected in its gaiety the determined efforts made to forget the horrors of that period. On the same lines the lecturer reviewed dress fashions, illustrated by slides, since the Napoleonic wars, giving instances of the fabrics utilised and brief descriptions of their characteristics. Reference was made to the changes due to the introduction of the bicycle and the motor car and to the demands that an active, sport-loving mode of life created. Light materials were a necessity; warmth being secured by fur overcoats and wraps. Discussing the introduction of fashions, Mr. Chapman assigned due consideration to the claim that Paris fashions were not always acceptable in this country and that sometimes Paris followed us. The court influence was referred to, but in the opinion of the lecturer the stage was the leader in fashion. In his opinion also a manufacturer could, at best, only introduce a fabric which would fit in with the prevailing mode. He next made reference to the difficulties faced by the manufacturer in trying to anticipate demands in style and colour, in trying to avoid overstocking, and in the employment of his plant to full advantage. He also pointed to the recurrence after a period of years of old style fabrics. Slubs knops, and knicker effects popular in 1884, and 1905 were now in fashion again. There were undoubtedly cycles in design too. In conclusion the lecturer referred to the requirements of the men. Changes were few and not very wide in range at any time. A plea was made for men to pay more attention to their general appearance as regards clothing.

The lecturer was accorded a hearty vote of thanks for this interesting lecture.

FEDERATION OF TEXTILE SOCIETIES AND KINDRED ORGANISATIONS

Annual Meeting at Nelson and Burnley

The annual meeting and conference of above-named Federation took place at Nelson and Burnley on Saturday, 2nd May 1931, when about 70 delegates attended from societies in Lancashire, Yorkshire, and the Midlands. The meetings were held by invitation on the part of Nelson Textile Society, Burnley and District Managers' Association, and Burnley Textile Society. The textile departments of the municipal training institutions in both towns were visited and inspected.

The following is a list of names of delegates who signed the attendance record—Accrington Managers' Mutual Association—J. J. Hartley, John Sutcliffe; Ashton-under-Lyne Mill Managers' Association—J. Burgess; Batley Textile Society—J. B. Sugden, N. Collinson; Blackburn and District Managers' Association—F. Briggs; Blackburn Textile Society—L. Haworth, W. B. Livesey; Bolton and District Managers', Carders', and Overlookers' Association—E. E. Richards,

J. Holt; Bradford Textile Society—H. Binns, E. M. Roberts, W. Hustwick; British Association of Managers of Textile Works—H. Nisbet; Burnley and District Managers' Association—E. C. Parker, E. Bird, R. G. Hodgson, A. Smith, J. Midgley, T. R. Bird; Burnley Textile Society—John H. Riley, A. H. Crowther, J. W. Thornber, E. Holden, G. L. Jackson, W. Munn Rankin; Bury and District Textile Society—J. Thomason, H. Barlow; Halifax Textile Society—H. Greenwood; Haslingden District Textile Society—H. Haworth, N. King; Huddersfield Textile Society—J. H. Redfearn, H. Holroyd; Leicester Textile Society—W. Dunmore, C. S. Lacey; Leigh Textile Society—J. W. Turner, J. Hindley, R. Ratcliffe; Manchester College of Technology Textile Society—J. Schofield, J. A. Kirby; Manchester Athenæum Textile Society—W. N. Wallis, G. H. Carter; National Federation of Textile Works Managers' Associations—S. Langshaw; Nelson Textile Society—J. Starkie, A. S. Parker, C Elliott, W. P. Richmond, F. Halstead, J. Rawson; Oldham Managers', Carders', and Overlookers' Association—H. E. Dawson; Oldham Technical Association—W. H. Slater, G. H. Thompson; Rochdale Cotton Spinning Mutual Improvement Society—J. H. Townson, J. W. Wolstenholme; Rochdale Textile Society—F. Coop, J. H. Lord, J. W. Pickering; Shipley Textile Society—Norman C. Gee, R. Jones; Textile Teachers' Association (Lancashire)—S. Watson; Textile Institute (Yorkshire Section)—A. Saville; Todmorden Textile Society—J. A. Scholefield, A. Fielden, B. Walton; Committee of Management—R. Entwistle; *Textile Weekly*—S. G. Shaw; Hon. Auditor—W. Kershaw.

Assembly at Nelson—Luncheon was served at the Nelson Hotel, when the Mayor of Nelson (Ald. Richard Winterbottom) welcomed the delegates, and said that when he realised the vast area which the various societies covered he could have no doubt of the benefits to be derived from being federated together. Nelson had perhaps weathered the depression storm better than many cotton centres, for it was mostly concerned with the fancy trade. The textile school had certainly made valuable contributions to the local industry. Ald. J. H. S. Aitken, C.C., J.P., Chairman of the Education Committee, welcomed the delegates and said the Federation ought to be of the greatest importance in strengthening the connection between technical education and the industry. The various societies might be most helpful by way of representation on local advisory committees in relation to technical training. Ald. Luke Thornber also spoke and said that after a long connection with technical school affairs he was more convinced than ever that in no sense should a technical school be regarded as a trade school. They did not exist for the teaching of particular trades but for the training of students so that they would be able to tackle their job intelligently in the branch they entered.

Mr. Collinson, as Chairman of the Federation, acknowledged the welcome and, later, Mr. Saville warmly thanked the respective societies for their kind hospitality.

Visit to Burnley—The party proceeded by special tramcar to Burnley, where the annual meeting took place at the Technical College. The Mayor of Burnley (Ald. Nuttall, J.P.) attended and offered a hearty welcome to the visitors. The Federation movement, he thought, was bound to prove useful both to the individual organisations and to the industry as a whole.

Mr. Norman Collinson (Batley), as Chairman, thanked the Mayor and then opened the annual meeting. He had occupied the chair for one year and would retire with pleasant recollections of his experiences.

Election of President—Mr. E. M. Roberts (Bradford) moved that for the future the Chairman be elected as the President and that the Committee of Management elect its Chairman from its own members. He proposed the election of Mr. J. W. Wolstenholme (Rochdale Cotton Spinning Mutual Improvement Society) as President. The motion was seconded and carried unanimously.

In accepting the presidency, Mr. Wolstenholme said he hoped they would find him a sincere worker. The delegates appeared to represent a vast and diverse experience and their mission seemed to be that of co-operation in regard to theory and practice. The industry generally was passing through a critical time and they must be prepared to try new methods. Change was inevitable, and it was surprising how much change had taken place in relation to cotton spinning in recent years. He was pleased indeed to accept the honour conferred upon him by his election as President.

Annual Report—The annual report of the Committee of Management was presented and adopted as follows—

At 31st December last, there were 35 organisations in membership of the Federation, as compared with 34 at the end of 1929. Shipley Textile Society has recently joined, bringing the total to 36. It is reported that a society is in course of formation at Belfast and affiliation is anticipated. The whole movement continues to spread and as the Federation exists for mutual assistance, the Committee of Management realises that its formation in 1927 following a series of meetings promoted for the purpose by the Textile Institute, has already proved highly beneficial to all concerned. Annual meetings and conferences have taken place at Leicester, Batley, Rochdale, and now at Nelson and Burnley, and the Committee records its best thanks to the organisations which have invited the delegates and undertaken responsibility for the Conference programme and also hospitality. The decision whereby the annual meeting is movable has proved both interesting and profitable to all concerned. The endeavour to secure that papers contributed shall largely refer to the special features of the textile industry of the districts visited has resulted in the provision of most instructive records in this connection. The Committee has met twice during 1930 and there has been one general meeting in reference to arrangement of lecture syllabuses. The latter meeting emphasised the importance of societies securing the services of young men for the contribution of papers. As to finance, it is gratifying to be able to record that, under conditions of merely nominal annual subscription, the organisation expenses are adequately met. The credit balance at 31st December 1930 was £9 odd as against £6 odd at the end of the previous year. The Committee has pleasure in recording its best thanks to the Textile Institute for meeting-room accommodation and secretarial service.

Election of Committee—The Committee of Management was re-elected with the exception that Mr. E. Holden (Burnley) and N. Collinson (Batley) take the places of Messrs. W. Kershaw (Manchester) and G. W. Haigh (Halifax); Lancashire—F. Briggs (Blackburn), E. Holden (Burnley), J. Burgess (Ashton), R. Entwisle (Accrington); Yorkshire—E. M. Roberts (Bradford), N. Collinson (Batley), H. Holroyd (Huddersfield); Leicestershire—W. O'Brien (Leicester); Textile Institute representatives—H. Nisbet (Manchester), A. Saville (Bradford); the Hon. Secretary-Treasurer (Mr. J. D. Athey) and the Hon. Auditor (Mr. W. Kershaw) were re-elected and thanked for their services.

1932 *Annual Meeting*—The Secretary reported invitations for next year's annual gathering, and it was decided to accept the invitation of Bradford Textile Society—for first Saturday in May 1932, or such other date as the Committee might arrange.

Conference—A conference followed when papers were contributed by Mr. J. W. Pennington, F.T.I., on "The Technical Side of the Local Textile Industry," and by Sir Amos Nelson on "The Cotton Industry and its Future." Mr. Pennington made some interesting references to recent changes as a result of the cotton trade depression. In 1925 there were 130 firms in the Burnley area operating approximately 108,000 looms, and by 1929 the figures were reduced to 112 and 90,000 respectively. It was computed that up to the present time 30,000 looms had gone out of action. Probably 75% of the looms withdrawn had been scrapped and the remainder sent abroad or sold for home use. The bulk of the fabrics produced were of standard, mass-production type, and not many years ago it was not uncommon to find many large firms whose entire production was limited to three or four kinds of fabric. The fierceness of competition, however, had brought about marked change in this respect. In one case, that of a fairly large mill, the variety had extended to nearly a hundred kinds. The percentage

of efficiency was astonishingly high in mills possessed of comparatively old machinery. Considerable reorganisation and re-equipment on modern lines was probably desirable, but the automatic loom alone would not solve the problem. In order to take full advantage of automatic looms, it was necessary to install modern systems of high-draft ring spinning, place yarn direct on to the automatic-loom pirn, and cut out intermediate processes. In that district, spinning and weaving units were detached, and the gap would have to be bridged before there could be much hope for successful automatic-loom weaving on standard cloths.

Sir Amos Nelson pleaded for a better outlook on the part of all concerned in the industry.

Votes of thanks terminated the proceedings.

NOTES AND NOTICES

Council Meeting

A fairly good attendance was secured for the June meeting of the Council of the Institute at Manchester. As the meeting was the first to be held subsequent to the Annual General Meeting of the current year, unusual interest attached to the proceedings by reason of the inclusion on the agenda of election of Chairman, other officers, and members of the various Committees. Mr. Henry Binns, of Bradford, who for many years past has contributed most generous service in connection with several Committees, including in particular the Selection Committee, was unanimously elected Chairman for the ensuing year, whilst Mr. Frank Wright, of Bolton, was elected Vice-Chairman. On acceptance of election, Mr. Binns said he appreciated greatly the opportunity which the office provided for service to the Institute. Mr. Nasmith had performed excellent work over the past two years, and it was pleasing to know that he intended to remain in close association with the whole movement which the Institute represented. The meeting elected Mr. Nasmith as Hon. Secretary, an office held for many years by Mr. W. Frost, who now desired relief from the office but accepted continuance of service in other directions. Mr. Frost was most heartily thanked for his past services, and Mr. W. W. L. Lishman was then re-elected Treasurer. The Chairman extended a cordial welcome to newly-elected members of Council in attendance—Messrs. H. C. Barnes, A. W. Stevenson, J. H. Strong, T. Woodhouse, and F. Wright. In regard to the appointment of Committees, it was decided that the Propaganda Committee be withdrawn and that the Finance Committee take over the work as the Finance and General Purposes Committee.

Federation of Textile Societies and Kindred Organisations

A meeting in reference to arrangement of lecture syllabuses was held at the Institute, at Manchester on Saturday, 6th June, when delegates were in attendance representing 20 textile societies in Lancashire and Yorkshire. The recently-elected President of the Federation, Mr. J. W. Wolstenholme, of Rochdale, occupied the chair and he congratulated the delegates on meeting together for the purpose of exchanging information and discussing matters of mutual interest to the benefit of all concerned in the movement. It was announced that the Bradford Textile Society had confirmed the invitation to the Federation to hold its next Annual Meeting and Conference at Bradford. Although a date for the event had been suggested, the Bradford Society were quite agreeable that the date might be considered by the Committee of Management of the Federation. At a meeting of this Committee, when Mr. J. A. Burgess, of Ashton-under-Lyne, was elected Chairman for the ensuing year, it was agreed to confirm the date of 7th May (Saturday) 1932, subject to the convenience of the inviting Society.

It was reported that there are now 36 organisation in membership of the Federation. The Committee received with profound regret the intimation of the death of Mr. Walter O'Brien, of Leicester, and ordered an expression of sorrow to be communicated to Mr. J. T. Stokes. A suggestion from Mr. Stokes that the Executive of the Leicester Society nominate a successor was accepted.

Textile Institute Diplomas

Elections to Fellowship have been completed as follows since the appearance of the previous list (April issue of this *Journal*)—

FELLOWSHIPS

CORDINGLEY, Hubert Brayshaw (Keighley).
STEVENSON, Alexander Wight (Galashiels).

Institute Membership

The election of additional Members of the Institute at the monthly meetings of the Council has proceeded at a satisfactory rate during the first six months of the current year It is noteworthy, however, that effort in the direction of introduction of new members has been largely confined to a comparatively small group of existing members—members who, over many years, have persistently availed themselves of every opportunity to advance the numerical strength of membership. In this connection, all members are cordially invited to co-operate in securing suitable new members. The General Secretary would be glad to forward copies of the Prospectus and Application Form to names and addresses provided by members of the Institute generally. When a request is made for an application form to be forwarded, however, it is an advantage if the member making the request is able to state that he is prepared to act as proposer.

At the May meeting of the Council, the following were elected to Membership of the Institute—H. G. Blydenstein, Blydenstein & Co., Enschede, Holland (in Spinning and Weaving Mill); Wm. Cunliffe, Wilson Bros. Bobbin Co. Ltd., Garston, Liverpool (Managing Director, Bobbin and Shuttle Manufacturers); S. B. Dalal, Khamasa Chakala, Ahmedabad, India (Spinning Master); A. Edge, I G. Dyestuffs Ltd., Cromford House, Cromford Court, Manchester (Director); J. Green, 24 Newton Road, Lowton, Lancs. (Retired Mill Manager); E. Green, 24 Newton Road, Lowton, Lancs. (Apprentice in Loom and Dobby Works); G. Herd, 6 Sedberg Street, Preston (Powerloom Overlooker); J. Jung, Jaegerndorf, Silesia, Czechoslovakia (Professor of Textiles); D. Laidlaw, 6 Laidlaw Terrace, Hawick, Scotland (Departmental Charge, Hosiery Factory), W. A. G. MacLean, Mill House, Cheadle, Stoke-on-Trent (Manager, Rope Factory); H. S. Newsome, F. S. Coles & Sons, 45a Jewin Street, London, E.C.1 (London Representative of Textile Manufacturers); R. H. Puttette, 54 Myrtle Avenue, Bingley (Finishing Department Manager); J. T. Wright, Trow Mill House, Hawick, Scotland (Manager, Spinning and Weaving Mills).

At the June meeting of the Council, the following were elected to Membership of the Institute—E. Brauer, Vereinigte Glanzstoff-Fabriken A.-G., Kelsterbach (Managing Director); J. Clifford, Sandhurst, 5 Arlington Avenue, Blackpool (Consulting Chemist); R. O. Hall, Ontario Research Foundation, 47 Queen's Park, Toronto 5, Canada (Research Chemist, Textiles Department); J. Mortimer, 12 Aireville Grange, Frizinghall, Bradford (Dress Goods Designer); S. M. Neale, College of Technology, Manchester (Lecturer in Chemistry of Cellulose); D. McL. V. Turnbull, 7 Buccleuch Place, Hawick, Scotland (Asst. Manager, Cleaners, Dyers, and Hosiery Finishers); G. A. Warman, 244 Archway Road, Highgate, London, N.6 (Warehouseman).

REVIEWS

Autumn Season Colour Card. Issued by the British Colour Council, London. This attractively produced pattern card may become a real asset to the retailers and producers of textiles as well as to the dye manufacturers, who can obtain from it information enabling them to match the standard season's shades beforehand. This aspect of the Council's production should not be lost sight of as any reduction of the multitudinous matching of shades which occurs in every dyeworks during an average season cannot fail to do its bit towards helping the inevitable trade revival. The stumbling block which the Colour Council will presumably do their utmost to remove, and which with adequate support from their constituent members should not be a great difficulty, is the inherent conservatism of the textile trades, which insist on going along their independent paths, without any regard for organised effort. If a retailer will order his shades by the card, dyers, printers, and dyemakers can all produce their best work by reason of adequate time being given to them for standardising and testing the colour mixtures necessary for the purpose. The card itself is bound in a rather too delicate tint which will soon look soiled and untidy with handling; some other form of back might be substituted with advantage. J.R.S.G.

Le Tissage de la Soie Artificielle. By Paul Luc. Published by "L'Edition Textile," Paris. (2 Vols., 385 and 573 pp., 150 Frs.).

These two volumes form a treatise on the manufacture and uses of artificial silk. A short history of the development of artificial silk is followed by records of production to the end of 1929 in various countries, and a list of firms formed to make artificial silk up to 1930 in the different countries. A description is given of the machinery and methods employed in the manufacture of artificial silk from viscose with short references to methods of producing strong viscose silk. The second part of the first volume deals with artificial fibres in general. The third part gives the characteristics of the various kinds of artificial silk. Physical and chemical methods are described for the differentiation of the various kinds of artificial silk, including the use of ultra-violet light. Simple methods for cutting sections of artificial silk are given with various diagrams and photographs showing the cross section of various kinds. Methods of measuring the denier are given, together with numerous tables, showing the various systems of counting yarns. The titration method of measuring denier is included. The various methods of measuring turns per inch, strength, and elasticity of artificial silks are dealt with and tables are given for strength and elasticity of many forms of artificial silk. Optical and dynamical methods of measuring the regularity of threads are fully described, also methods of measuring lustre. The fourth part deals with methods of measuring humidity, whilst the fifth part gives a fairly complete bibliography of natural and artificial silk. The first volume ends with tables of weights and measures, thermometric scales, densities, etc., and an index. The first part deals with machinery and methods of sizing in hank, from bobbin to bobbin, in warp and other methods with various data concerning the various kinds of sizing materials suitable for artificial silk. The second part deals with the employment of artificial silk as weft, and describes various methods and machinery for winding artificial silk on bobbins and directly on pirns. Diagrams are given explaining how knots are to be tied and also how various knotting machines operate. The third part deals with the employment of artificial silk as warp, and describes various methods and machinery for warping and for processes relating to it. The fourth part deals with the weaving of artificial silk and describes various forms of loom and numerous types of fabric made from artificial silk. The fifth part deals with faults in artificial silk fabrics, brilliant threads in warp and weft, barriness in plain and in dyed fabrics. Calculations relating to the employment of artificial silk in fabrics are given, also methods of washing and of dry-cleaning artificial silk fabrics. A list of makers of plant used in weaving artificial silk is given. This volume finishes with a useful index. The two volumes should be very useful to those interested in the use of artificial silk, particularly for weaving. W.H.

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PROCEEDINGS

AN OBSERVATION ON THE COMPARATIVE RESISTANCE OF DRY AND OILED WOOLS TO ATTACK BY DERMESTIDÆ

By H. Clayton Hartley, A.T.I.
(late Dept. of Technical Education, Cairo, Egypt)

INTRODUCTION

Animal fibres are particularly liable to attack by Dermestidæ, and in Egypt the ravages of this pest have caused serious concern to the authorities from time to time. The various Government administrations find great difficulty in storing quantities of material composed wholly, or in part, of animal fibre, and constant supervision is essential if the stocks are to be kept even reasonably free from attack by the popularly termed "woolly bear." The usual precautions taken, namely, periodical exposure to light and air and a liberal application of flake naphthalene, are fairly successful if frequently and thoroughly carried out, but are by no means absolutely reliable Particular anxiety was caused to one administration by the fact that large stocks of wool yarn were constantly carried in store in various parts of the country for the manufacture of hand-tufted carpets and rugs. These yarns were hand spun from native wool, and, as the latter contained only a small percentage of natural fat, it was unscoured except for a cold water scour of the entire fleece after shearing to remove sand and dust. The stocks of this yarn suffered considerable deterioration from time to time, largely due to the depredations of woolly bear grubs, *Anthrenus fasciatus* being the common variety. Subsequently, a modern worsted spinning plant was installed for the production of carpet yarns on the Bradford system, the wool being scoured and combed in oil. The stocks of yarns now increased enormously, with a corresponding increase of anxiety on the part of those responsible for their custody.

OBSERVATION

Samples of various materials were kept in the writer's office in Cairo in the ordinary course of events. These were kept in drawers in a warm dry room, and thus conditions were favourable to attack by woolly bear, and from time to time the contents of these drawers had to be destroyed owing to damage from these pests. When samples from the new worsted plant began to materialise it was noted, after a while, that whereas samples of raw wool, old hand-spun yarn and scoured wool, frequently had to be renewed, those of tops, noils, rovings and yarn appeared to be untouched. This suggested that the presence of oil added to these samples might be the reason for their immunity from attack, and the following tests were, therefore, made to confirm this theory.

EXPERIMENTAL

Samples of wool, yarns, etc., were collected, as follows—

Sheet 1—*Sample "A"*	...	Raw greasy wool.
Sample "B"	...	Scoured wool.
Sample "C"	...	Top in oil.

All the samples were approximately the same size.

SHEET 2—*Sample "D"*	...	Hand-spun yarn from raw greasy wool.
Sample "E"	...	Hand-spun yarn from raw greasy wool.
Sample "F"	...	Machine-spun yarn in oil.
Sample "G"	...	Machine-spun yarn in oil.
Sample "H"	...	Machine-spun yarn in oil.

All the samples were approximately the same size and were composed of wools of varying natural colours.

SHEET 3—*Sample "J"*	...	Specimen of hand-made carpet. The pile-yarn is hand spun from raw greasy wool.
Sample "K"	...	Specimen of hand-made carpet The pile-yarn is machine spun in oil.

In both specimens the ground structure of the carpet is cotton.

PLATE I

Sample "A"
Raw Greasy Wool ... . Almost totally destroyed

Sample "B"
Scoured Wool ... ... Badly damaged

Sample "C"
Top in Oil ... ... Untouched by Dermestida

These represented wool in the natural greasy condition, clean wool, and wool with added oil in various stages of manufacture by hand or mechanical means. These sheets were placed in a box with a well-fitting lid to exclude light and air, and some thirty specimens of "woolly bear" were placed on the samples of wool fibres with added oil, in order to see if these would be attacked. The box was then placed in a warm dry cupboard, and left for several weeks. On examination at the end of this period it was found that the samples were in the stated conditions, the extent of the damage being clearly revealed in the photographs.

CONCLUSIONS

From the result of these experiments it is evident that whilst the *natural* oil or grease present on the wool fibre is not a deterrent to attack by woolly bear, added oil as used in spinning does effectively protect the fibre against damage by this pest Thus raw wool scoured wool and hand spun yarn made from either of these requires constant supervision to protect it from damage, whereas machine spun yarn stored in the grease is perfectly safe It naturally follows therefore that yarns spun in oil on the Bradford system provided that they are stored in an unscoured state are much more satisfactory in countries where Dermestidæ are a serious problem than yarns dry spun on the French or Continental system The presence of oil in the former makes storage of the yarns perfectly safe whereas the latter are likely to suffer serious and costly damage It is also thought that this added oil acts as a protection against moth but circumstances prevented the confirmation of this belief by definite experiment

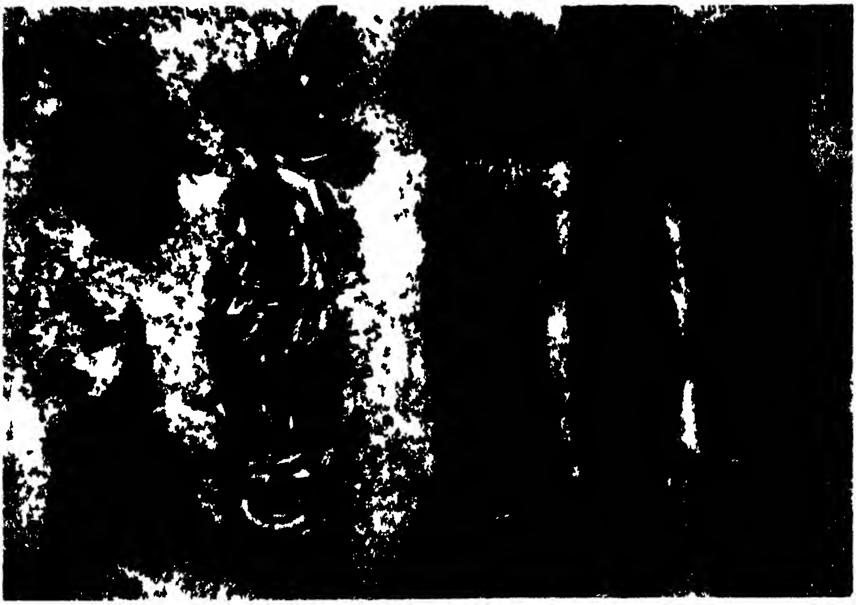

PLATE II

Sample "D"	
Hand spun Yarn from Raw Greasy Wool	Totally destroyed The effect here is very marked only a few wool fibres being left
Sample "E"	
Hand spun Yarn from Raw Greasy Wool	Considerably damaged
Sample "F"	
Machine spun Yarn in Oil	Untouched by Dermestidæ
Sample "G"	
Machine spun Yarn in Oil	Untouched by Dermestidæ
Sample "H"	
Machine spun Yarn in Oil	Untouched by Dermestidæ

PLATE III

Sample "J"
Specimen of Hand-made Carpet. The Pile Yarn is Hand-spun from Raw Greasy Wool

The Wool Pile is considerably damaged In the centre the pile is totally destroyed, revealing the cotton ground structure. The complete destruction of the entire pile is merely a question of time

Sample "K"
Specimen of Hand-made Carpet The Pile Yarn is Machine-spun in Oil

The Wool Pile in this is untouched by Dermestidæ.

Subsequent experiences, however, of the storage of large quantities of wool yarn in oil confirmed these conclusions. No difficulty was experienced in avoiding loss or damage from attack by these pests provided that the yarns were stored in oil, and scoured as and when required for use.

Acknowledgments are expressed to Mr. A. Land, A.T.I., of Bradford, who photographed the specimens.

London Section

Meeting held at the Institute Rooms at 104 Newgate Street, London, on Wednesday, 28th January 1931, Mr. L J. Mills in the chair

FURNISHING FABRICS

This lecture was delivered by Mr. H. Woodman, of Messrs. Warner & Sons, taking the place of the late Mr. E. B. Fry, who was prevented from lecturing by the death of his only son.

The lecturer indicated that the present-day demands were continuously for something new—new designs, new colourings, and new textures all were constantly being sought. Cheapness was being secured by the substitution of cotton and rayon for real silk, but there were limits beyond which it was unwise and uneconomical to go. Nevertheless there was yet a real demand for really first-class fabrics. An example of such a fabric was shown. Mr. Woodman described, and illustrated by means of slides, the processes followed in the production of furnishing fabrics from the yarn to the finished goods. Special reference was

made to the manufacture of pile fabrics. Slides were shown of "period" fabrics, from the early Italian to modern designs.

The lecturer was accorded a hearty vote of thanks not only for his excellent lecture, but for his kindness in stepping into a breach at such short notice.

Meeting at the Institute Rooms, 104 Newgate Street, London, on Wednesday, 18th February 1931; Mr. John Howard presiding.

COTTON SPINNING PROCESSES

Before asking the lecturer, Mr. L. J. Mills, to commence his address, the Chairman referred to the great loss the Institute had sustained by the death of Mr. E. B. Fry (Fellow). The meeting resolved to convey to Mrs. Fry its sincere sympathy with her in her bereavement.

Mr. Mills delivered "a bird's-eye view of the processes of spinning and weaving cotton." He dealt briefly with the history of cotton, the structure of the cotton hair and its spinning properties, and made reference to the various aspects of Empire cotton growing. A résumé of spinning processes followed and slides in illustration were shown. Automatic looms and the necessary yarn preparation to make their use a success were discussed, reference being made to successful advances in winding. Some reference was made to the relative merits of ring and mule spun yarn, each having specific advantages and disadvantages. Following the lecture, questions were asked relating to the incidence of ring-spinning in this country and on the Continent, and to the financial considerations involved. The lecturer was asked to consider continuing and expanding this lecture into a series, and to make one of the series a talk on "Yarn Preparation." He kindly consented to do so, and a hearty vote of thanks terminated the meeting.

Meeting at the Barratt Street Trade Schools, London, on Thursday, 12th March 1931; Mr. W. C. Eaton, Board of Education, presiding.

"SALESMANSHIP"

The Chairman, introducing Sir Francis Goodenough, the lecturer, said that as Chairman of the Government Committee on Education for Salesmanship, Sir Francis had made the subject peculiarly his own and his name in connection with this subject was a household word. He doubted if any committee of recent times had aroused such general interest. He thought the position in regard to education for commerce could be put briefly thus—The field was for the first time being explored and surveyed by the committee to which he had referred and of which Sir Francis was chairman. The report of that committee was being eagerly awaited. From that report could be determined what development of the existing provisions was required. He urged that in the face of intensified foreign competition we could not allow our training schemes for salesmanship to lag behind those of our competitors. It should be our aim to get ahead of them in this direction as in all others. He had the greatest pleasure in calling on Sir Francis Goodenough to address the meeting.

Sir Francis said that he wished to talk particularly on the principles of salesmanship, or rather the principles of commerce, for after all salesmanship was the very heart of commerce. The best brains in every commercial undertaking should be concerned with securing business for the firm- in other words, in salesmanship. The old slogan, "Business is business," with its implication of a different code of honour for business from that of everyday life, was now agreed to be wrong; business was coming to be recognised as service for mutual profit. He urged the adoption of the motto "Service First" for business conduct; its adoption would ensure the right mental attitude towards the customer who was the most important person in business. The customer must be regarded as the employer, since from him came the money to pay salaries, rent, materials, and dividends. Sir Francis then went on to say that having secured the right attitude

towards the customer, the next and natural step was to study his needs, habits, and circumstances in every possible way. Your aim should be to secure the lasting satisfaction and growing confidence of your customer, since then, and then only, would the customer come back with repeat orders. Your word must be equal to your bond, and your performance equal to or better than either, in quality, quantity, and time of delivery. He strongly emphasised the value of performing faithfully what had been promised, and illustrated his point with instances from the conduct of the Gas Light and Coke Company, with which he was connected. Defining some of the definite laws in business, Sir Francis said that the first was that customers gravitated towards the form that paid most attention to their needs and wishes. The next was, perhaps, that every complaint was to be treated with the greatest seriousness and attention; such complaints were at the outset always justified in the customer's mind. Customers who did not complain but kept them in reserve, or, worse still, discussed them with their neighbours but not with the firm concerned, were difficult to please subsequently, and perhaps impossible to retain. He insisted, too, on complaints being dealt with personally as far as possible; correspondence was far from being satisfactory in this connection. Furthermore, he urged if you found a complaint was justified, remedy it quickly and liberally. Next, the lecturer discussed sales personality; what were the qualities called for in the salesman, and how could education help to produce or train these qualities ? The first such quality was good character; the next good personality, the capacity for making friends. In this connection a good general education could broaden the mind and widen the interests so that it proved easy to make contact with the interests of the customer. He gave an illustration of the value of being able to interest yourself in the hobbies of your customer, from his personal experience. Next to character and personality, said the lecturer, came knowledge—a thorough knowledge of your busines and of what you had to sell. Then followed the most difficult part; having character, personality, and knowledge, there followed application, and this was the aspect of salesmanship in which there was, as yet, little of guidance available. Every industry would have to make its own study in this direction and make it as soon as possible and as earnestly as possible. Though he did not think everyone could be made into a good salesman by training and education, there was no doubt that much could be done. More than ever to-day we needed good salesmen and good salesmanship. The question of salesmanship was, in the lecturer's opinion, the most important question of the day to manufacturers and merchants. We could not regain lost markets nor retain those we had if we lagged behind our competitors in this direction. He believed, however, that we should not fail but should ultimately achieve success—though he uttered the warning that optimism was not to say, "We shall be all right," but "I will make it all right."

After a short discussion, in which Sir Francis made it clear that salesmanship meant, firstly, the design and production of goods that would sell, a hearty vote of thanks was accorded to the lecturer, who briefly responded.

NOTES AND NOTICES

Institute Employment Register

The following are summaries of particulars registered by individuals seeking employment. Full particulars may be obtained by application to the General Secretary—

No. 58—Textile machine erector seeks engagement as overlooker and would accept part-time teaching. Mill experience at home and abroad— Rings, speeds, drawing. Honours in spinning. Age 37.

No. 59—Post desired as manager, assistant manager, or preparation manager or supervisor in mill using cotton, silk, and rayon yarns. Age 6. Technical qualifications and experience.

Textile Institute Diplomas

Elections to Associateship have been completed since the appearance of the previous list (July issue of this *Journal*)—

ASSOCIATESHIPS

HARRISON, John Harold (Preston).
STOTT, George Selwyn (Keighley).
PRUCE, Henry (Nottingham).
GRIFFIN, Arthur James (Nottingham).
JOHNSTON, Ebenezer Young (Alva, Scotland).
BOOTHMAN, Thomas Beresford (Oldham).
WALKER, Warren (Matlock Bath).
MORRIS, Leonard (Bolton).
WALKER, Thomas Wood (Oldham).
WRIGHT, Charles James (Paisley).
DUNKERLEY, Frank (Oldham).
FOULKES, Thomas Frederick (Manchester).
HEATON, Norman (Keighley).
CROMPTON, Richard (Bolton).
DUXBURY, Henry (Bolton).

Institute Membership

At the July meeting of the Council, the following were elected to Membership of the Institute -Wm. Cowpe, Shelling Hill, Cullybacky, Co. Antrim, Ireland (Chemist); H. Goodall, Sterling Silks Ltd., Shearbridge Mills, Great Horton Road, Bradford, Yorks., (Managing Director); A. B. Johnstone, Glenroi, Blantyre Road, Swinton, Manchester (Departmental Manager's Assistant); A. Jones, 29 Elliott Street, Silsden, near Keighley (Textile Designer); D. Kwok, 55 Markham Road, Shanghai, China (Assistant Manager, Textile Manufacturers); N. S. Pearse, General Secretary, International Federation of Master Cotton Spinners' and Manufacturers' Associations, 238 Royal Exchange, Manchester; D. B. Sykes, c/o Robert Jowitt & Sons Ltd., P.O 153 Durban, South Africa (Director); R. Wilson, Armitage & Rigby, Cockhedge Mills, Warrington (Trainee Manager).

INQUIRIES

The Institute's information resources are being called upon more and more frequently, and it has recently been decided to publish certain inquiries with a two-fold object in view. In the first place it is felt that the interests of the inquirer are better served by so doing; while secondly, other members may simultaneously be benefited. The first such inquiry to be published is from a member who asks—

1. **What are the results of any tests undertaken to determine the power taken to drive Ring Frame spindles on the tape system as against ordinary bands?**

Members who can furnish information in reply are asked to communicate with the Editor indicating whether their reply is confidential to the inquirer or whether it may be published in this *Journal*.

REVIEWS

Textiles on Test. By J. Guilfoyle Williams. Published by Chapman & Hall Ltd., London, 1931. (181 pp. and Index, 7s. 6d. nett.)

The sub-title of this book is "A Study for Distributor and Consumer of the Wearing and Washing Properties of Fabrics and Garments." The author, who is a chemist responsible for the testing of textiles for a large London store, has brought together much information intended to aid the manufacturer, distributor, and consumer in judging the quality and serviceability of textile goods.

General facts relating to the composition, preparation, and examination of fabrics occupy twenty-five pages. In this chapter simple tests are described for recognising the fibre or fibres, of which a material is composed and the meaning which should be attached to such terms as *woollen*, *linen*, and *silk* are discussed. Various manufacturing and finishing processes are briefly outlined, chiefly from the point of view of their relation to the serviceability of the product.

The next chapter (fifty pages), devoted to the behaviour of textiles in wear and wash, discusses such subjects as frictional wear, shrinkage, and the deterioration of fibres under the action of light, mildew, perspiration, and other agencies. We give three quotations from this chapter which may illustrate the nature of the numerous subjects discussed—

"In another case a rayon stockinette garment was returned with a number of small tears or cuts in the fabric. Investigation showed that if the fabric was ironed while damp with a cool iron and the toe of the iron pressed suddenly on the fabric, similar small tears or cuts were produced. With a hot iron this damage could not be produced, for the rapid drying of the rayon restored it to normal strength, and it could then resist such a treatment."

"A mackintosh is not porous, and so during wear there is a layer of stagnant air retained inside. This air becomes heated by the warmth of the body, and humid owing to moisture breathed out by the skin and also from the water evaporated from the clothes (more especially if they had become slightly wet before the mackintosh was worn). In consequence it is quite obvious that on occasion water will condense on the inner surface of a mackintosh owing to the cooling of the outer surface by wind and/or rain. It is equally clear that the customer is not unreasonable in believing that water is penetrating the proofing To prevent or minimise condensation a mackintosh should be loose fitting and also possess such other ventilation as is possible."

"It is often stated that the process of rendering wool unshrinkable destroys the wearing properties, and, moreover, that the effect is not permanent. The author has examined three wool, winter-weight, vests which were purchased in the autumn of 1924, and worn six months each year; the three vests had not shrunk or thickened in May 1930, that is after six years of service, but at the bottom of the back the fabric had worn somewhat thin. They had been washed at different times by many laundries and washerwomen, and some of the treatments were known to have been severe. They were still quite serviceable vests. This disposes of both the statements quoted at the commencement of this paragraph"

Thirty-four pages deal with "Colour in Wear and Wash," and twenty-seven pages are devoted to washing, laundering, and dry-cleaning. The next chapter (twenty-four pages) is a discussion of "Complaints from Customers." We give a typical quotation—

"In the case of complaints against fabrics known to be satisfactory in normal use, hot-ironing effects may be suspected. Careful inspection of the article will often give evidence when such damage has occurred. The shape of the iron may show, or more frequently it will be found that where two thicknesses of cloth overlap the protected portion is unaffected Care must be taken to ascertain that such colour-change is not due to sunlight fading. In a complaint the author investigated against "fadeless" casement, the actual cause of the fading was hot-ironing."

In the concluding chapter the author advocates the formation of a "Textile Distributor's Research Association," which should undertake "a deliberate study of the service value of textile fabrics in conditions of use" and serve the mutual interests of manufacturer, distributor, consumer, and launderer.

A defect which is almost inevitable in a book written from this viewpoint is that general statements are made on the strength of particular instances, but if this book is widely and thoroughly read by the staff of distributing houses and by the man in the street, it should do much towards ensuring that the consumer is supplied with articles which give satisfaction. One difficulty, however, must be faced, namely, that a decision as to whether an article is defective or has had

unfair treatment in use (or laundry) can in a very large number of cases only be reached after a very careful examination by an expert thoroughly trained in textile science, and then only if a properly equipped laboratory is available. Large textile distributors can clearly benefit by running a testing department under the control of a capable investigator, but smaller houses cannot bear this expense. It is not reasonable to expect that the heads of distributing firms, less still the ordinary salesman, can make proper use of information such as is to be found in this book, although simpler complaints, such as misrepresentation of the composition of a material, or defective make-up, might often be adequately dealt with. In difficult cases a method which is often available for dealing with a customer's complaint is for the distributor to refer it to the manufacturer, and for the latter to refer it to the appropriate Research Association. The difficulty that the manufacturer is often not a member of the Association (as is the case of foreign goods, particularly) would disappear if the distributor were to become a member of an Association having a working arrangement with the Textile Research Associations.

As an example of a class of defect which it is often extremely difficult, and frequently impossible, to trace to its source, we may mention the appearance of holes in table linen and the like after it has been washed a number of times. This type of complaint can only be properly dealt with by the expert in the laboratory, and in many cases the only aspect that can be fairly given is that "we consider it impossible from an examination of the sample to form a definite opinion as to the cause of the damage." Such a report may not be helpful but it is preferable to one which ascribes the damage to a definite cause on insufficient evidence. Such considerations indicate the need for a body, or bodies, to which goods which have not given satisfaction may be submitted, but the writer feels that it would be more satisfactory to all concerned if the proposed Textile Distributors' Research Association referred those complaints which it considered were due to manufacturing faults to the Research Association of the appropriate textile industry.

The book is well illustrated and is very fully indexed. Numerous useful references to the textile literature are given in footnotes and in an appendix.

W.H.G.

Technical Terms in the Textile Trade—A Dictionary of Yarns, Cloths, Makes, Weaves, and Terms, for Spinners, Manufacturers, Merchants, Distributors, etc. By Eber Midgley, F.T.I., Professor of Textile Industries, Technical College, Bradford. Vol. I, Cloth Terms. Emmott & Co. Ltd., Manchester. (Crown 8vo., pp. 326, Figs. 185. Price, 21s. nett.).

The compiling of a dictionary or glossary of technical terms as used in the textile industry is of such magnitude that any author who undertakes so formidable a task deserves the gratitude and appreciation of all who are in any way concerned with the numerous products of that industry, whether as manufacturers, merchants, or consumers. Professor Midgley is to be congratulated on attempting to compile a dictionary comprising over 2,300 textile trade terms, "the definitions of which," the author admits, "would have been impossible without the co-operation of individuals closely connected with every branch of the textile industries." This work is the culmination of a task which the author commenced twenty-six years ago (1905) as a contribution that was published under the title of "Standardisation of Trade Terms," and continued at intervals, extending from 1914 to 1921, as a series of articles, appearing in *The Textile Manufacturer*, under the title of "Definition of Cloth Terms in the Bradford Trade."

The present volume is the first of two companion volumes which the author believes to constitute "the first comprehensive encyclopædia of its character to be prepared." Volume I embraces Cloth Terms, and Volume II, Terms Applied to Raw Materials, and those used in all the operations from the fibre to the finished cloth, and in the definitions of which the author says he has "spared no effort to secure authentic and full information." Nor has he "confined himself to the production of a technical dictionary merely, but has taken the opportunity to deal more fully with terms descriptive of various fabrics. These terms have been amplified by the inclusion of details of the principles underlying cloth construction in general, whilst the particulars of the production of all types of cloths manufactured in the area of which Bradford forms the centre, are fully

described." This feature of the work, in fact, is so very pronounced that its general utility will be restricted chiefly to the Bradford trade in particular, and the woollen and worsted industries generally, while the work is inherently and conspicuously weak both in the amount and character of the information conveyed in the definitions relating specifically to the cotton and other branches of the textile industries. This, indeed, is the almost inevitable result of a specialist and recognised authority in his own particular branch of the textile industry attempting the virtually impossible task of defining the textile trade terms used in other branches of the industry with which he is less intimately conversant. And though this criticism in no wise is meant to cast any reflection (nor, indeed, does it in the very least reflect) upon the merit and authority of the work under review, it does, nevertheless, most certainly emphasise the fact—in the compiling of a work of this character, and in order to make it of general utility as the recognised standard authority possessing a legal status that will be respected and acknowledged by all branches of the textile industry—that it may be successfully carried into effect only by the collaboration of textile experts in each one of the several branches of industry concerned.

In fact, to-day, more than at any other period, there exists the need for a standard glossary of textile fabrics in particular, and of textile trade terms in general. And this, notwithstanding the fact that during the past thirty years textile glossaries have been produced in abundance both in this country and in America, and are to be found in numerous treatises on textile subjects, in trade journals, textile year books, as well as textile glossaries, dictionaries, and encyclopædias, all of which are of the same general character; and while the present work augments, it cannot truly claim to supplement, still less supplant, the numerous published works of a similar character.

In a work of this description, it is almost inevitable that discrepancies will occur, some of which should not have escaped observation and correction in the proof. Two examples occur on page 100, when, after stating that ". . . all types of union fabrics are *stretched to some extent during finishing*, the approximate variation of cashmeres from loom to finished cloth being as follows:" the following particulars are given as an example showing the amount of *stretching*—

		Width		*Length*
Reed (i.e. width in loom)	...	$49\frac{1}{2}$ in.	...	70 yards
Grey cloth	...	48 ,,	...	64 ,,
Finished cloth	...	44 ,,	...	66 ,,

This will tend to confuse students and others seeking information. The second example is seen in Fig. 65, a diagram illustrating the structure of "Catgut,". . . "a peculiar type of gauze weaving in which the warp threads make a double crossing between each pick." This diagram represents each pair of (doup and standard) warp threads actually crossing (or twisting) each other in the *same direction continuously and uniformly*. Such a structure as this is obviously impossible in gauze weaving with a "doup" or "leno" harness. Actually, a full crossing or twisting of doup and standard warp threads is effected by causing the doup slips to completely wrap around their fellow standard threads as the slips pass from the doup threads to the heald stave on which they are contained. Thus, whenever a "shed" is formed, whether it be an open or a cross shed, the doup threads are raised and depressed in alternate succession *always on the same side* of their respective standard threads, thereby causing them to make a full crossing or twisting, but in *reverse directions* alternately.

While it is the essence of a dictionary or glossary to be brief and concise, yet clarity should not be sacrificed for brevity that gives an indefinite and vague description, as in many instances that could, if space permitted, be cited. On the other hand, the amount of space devoted to many varieties of fabrics is quite disproportionate to their relative importance, whether technically or commercially. For example, the definition of "brocade," as "a rich texture of an elaborately figured description," certainly has the merit of brevity but not of utility, as it conveys not the slightest conception of the type, structure, nor textural features of this important type of fabric, with its infinite variety of textures. The definition given is applicable to numerous types and varieties of fabrics that have nothing at all in common with brocade fabrics, excepting that they are constructed from warp and weft threads.

On the other hand, no less than ten pages are devoted to the different styles and varieties of "alpaca fabrics," 15 pages to "Bedford cords," 7½ to "blisters" (dress fabrics), 8 to "crepe weaves," 3 to "herringbone" (twills), 8 to "honeycombs," 3 to "hopsack weaves," and 4 to "Venetians."

The book is profusely illustrated with the aid of line diagrams and working designs (on point paper) of the numerous weave structures; also by excellent photographic reproductions of the fabrics described; while a considerable amount of valuable data gives full particulars of the manufacture, counts, and character of the warp and weft, ends and picks per inch, and the finishing of the majority of types and varieties of the fabrics. This will be of considerable value, especially to those concerned with the manufacture of woollen and worsted fabrics and those varieties constituting what is known as the "Bradford trade." For a book of reference of this character, however, the price of 21s. is high. H.N.

Worsted Open Drawing. By S. Kershaw, F.T.I. Published by Sir Isaac Pitman and Sons Ltd. (128 pp. and Index, 5s. nett.)

Primarily intended for the assistance of those who have the actual drawing of wool to perform and for prospective workers in worsted yarn manufacture, this monograph on worsted open drawing constitutes an eminently useful review of the machinery involved and the processing methods employed. So much has been published on this subject that in a book of this kind, where the desire is to be descriptive rather than fundamentally illuminative, it is difficult to find anything new to record. The author, however, draws largely upon a wide and extensive experience as mill manager and textile technologist and gives readers the full benefit of his practical knowledge and theoretical studies, with the result that this new presentation of a well discussed subject may be considered in every way reliable, and consulted by those in the trade with the fullest confidence. The treatment of the subject is in accord with established practice and constitutes a useful record of present day procedure with respect to roving preparation on the "open" system, which, as the author states is the system by which 75 to 80% of wool tops are processed. All the salient features of the several drawing operations, from gilling to roving inclusive, are lucidly explained, the essential mechanical and material calculations required by drawing overlookers and managers are fully set out and explained, accompanied by several useful graphs and tables indicating the different drafting doubling requirements for various classes of wool and mohair. The illustrations contained in the work are well done and exceedingly helpful to an understanding of the text; this is especially true with respect to the diagrams relating to the calculations. From this simply-written work the reader will receive a sound, well balanced and complete description of worsted drawing which will prove of great interest to managers, overlookers, and students in the industry. J.D.

The Design of Capacitor Motors for Best Starting Performance. By B. F. Bailey. Department of Engineering Research, University of Michigan, U.S.A., Bulletin No. 19. (Price, 50 cents, 25 pp.).

Single-phase motors, as well as three-phase motors, are used to a very large extent in America, whilst in this country the three-phase motor is favoured for the majority of applications. American practice has resulted in the development of the capacitor motor, which has two windings, one directly connected across the line and the other connected across the line in series with a condenser. Best results are secured by using a comparatively large value of capacitance during the starting period and reducing this during the running period, the change being made automatically either by centrifugal switch or by relay. It is claimed that these motors have better efficiencies and power-factors than other types of single-phase motors, have excellent starting characteristics, are notably quiet in operation, and are simpler than other comparable motors. The pamphlet by Professor Bailey discusses the design of these motors, outlining the fundamental theory and giving the vector and locus diagrams, and a determination of the complete starting performance for a typical motor. The effects of (1) alteration of the ratio of turns in the two windings, (2) variation of the capacitance, upon the performance of the motor are analysed, and a discussion of the advantages and disadvantages of electrolytic and paper condensers is included. The conclusions reached are that capacitor motors can be designed to take care of a wide range of torque requirements by varying the capacitance and turns in

the starting winding, but that the cost of condenser and motor must be kept low, the torque ample and the starting low, if the machine is to become a general purpose motor. The capacitor motor undoubtedly is a good proposition from the point of view of efficiency, and on account of the fact that the unit may be designed to run at nearly unity power-factor. The cost, however, is higher than that of an ordinary motor, and larger units of this type would be excessively expensive and would not compare favourably with a synchronous-induction motor, or with an induction motor and phase advancer. Consequently the capacitor motor is limited chiefly to small sizes for general utility work, and therefore should have a wide field of application in view of the advantages it possesses. It should be therefore of considerable interest and importance to textile technologists and electrical engineers engaged upon textile electrification work.

R.H.W.

Jute: 1931. Published by the British-Continental Jute Press Ltd., 54 Fleet Street, London, E.C.4. (Price, 10s.)

A welcome addition to the few Textile Year Books is that under the title "Jute." In the 98 comparatively large pages, each page in the English and German languages side by side, is a large amount of information dealing with many important commercial and industrial phases of the jute industry. These include several interesting short descriptions on the following subjects -History, cultivation, industrial application, seed problem, statistics of various kinds, reviews, organisations and their effect upon raw jute prices, import duties, research and the need for further concentration on same, various crops and their effects upon the required quantity of carrying material, various kinds of jute fabrics and suggestions for new applications, short description of modern jute machinery, and substitutes suggested for replacing the jute fibre in cases of emergency. As this is the first year of "Jute," the publishers apologise for its incompleteness, but state that future year books will be enlarged and efforts will be made to keep future issues abreast of the times. But even in its present form, much information is given that is not available in the usual literature of the trade, and for this reason alone, the publication can be recommended to persons in all sections of the jute industry. Complaints are made of the apathy of British jute spinners and manufacturers in regard to the supply of statistics concerning the extent of their equipment; it is regrettable that more particulars on this point cannot, at present, be obtained, but it is to be hoped that more data will be given in future issues of the year book. When this information is given in a collective sense, it would probably do more good than harm to the country concerned.

T.W.

Methods of Hand Spinning in Egypt and the Sudan. By Grace M. Crowfoot. Published by the County Borough of Halifax, Bankfield Museum. (48 pp. with illustrations and Index. Price, 3s.)

This is a work published by the Halifax Museum's Committee, and is well worthy of the honour of being included in the series of Bankfield Notes which the Museum issues from time to time. Mrs. Crowfoot, the author, is both well read in the subject and so deeply interested in it that she has travelled far and wide, in the districts mentioned, in order to obtain first hand definite information on what might be termed the origins of spinning. The book is fully illustrated with photographs and drawings taken on the spot and showing the natives actually spinning in the several ways described. Hand spinning naturally cuts out the employment of what is generally understood as mechanism. The book is therefore devoted to methods long in use before any form of spinning wheel was invented, and yet methods that are still extensively employed in Egypt and the Sudan, and probably in many other places at the present day. It is extremely interesting to be able to trace the gradual development of hand spinning from the simple process of twisting fibres together by the use of the fingers of both hands to the highly developed method of the suspended spindle spinning made familiar to us by classical pictures of Greek and Roman artists. To the serious student of spinning, these various steps, in the growth of spinning, are familiar, but there has always been some degree of indefinitness in the methods of operation. Mrs. Crowfoot's work remedy's these faulty descriptions and references, and one can now clearly see from the photographs and the excellent explanations how yarns of various degree of fineness and of different fibres are produced and also doubled. The book is strongly recommended for the bookshelf of all interested in textiles. W.S.T.

Die Ramiekultur. By Prof. Dr. Kempski. Published by Thaden A.-G., Hamburg, 1931 (116 pp. 5 Marks.).

This book is one of a series of small handbooks published on the cultivation of tropical plants of economic value. The author writes from personal experience in growing ramie both experimentally and on a large scale. He is convinced that adequate markets could be found for the fibre if supplied in sufficient quantity and prepared by suitable machinery. The distinguishing characteristics of the fibre are described, and its superiority in many respects over other fibres is emphasised. It is suggested that its greater elasticity might lead to its being used more frequently in conjunction with flax, in order to counteract the tendency of the latter to crease. The greater part of the book is devoted to the cultivation of the plant and the various methods of propagation. Ramie is less specialised in its requirements than many other tropical plants, and may, therefore, give a profitable return when conditions are unfavourable to other crops. Also, every part of the plant may be utilised, and it seems probable that the leaves, in addition to serving as manure, might be used instead of mulberry leaves as food for the silkworm. The different types of machinery used in the preparation of the fibre are briefly described, and an outline of the working costs is given. The very high yield per acre of ramie fibre—according to the author it is ten times that of cotton—enables it to be sold at a low price, but it is not expected to displace cotton or any other textile fibre. Its peculiar properties should open up special markets, and the waste products of the plant, e.g. the wood, might provide valuable supplies of raw material for the manufacture of paper, artificial silk, etc. The book is illustrated by fifty photographs, and concludes with a large bibliography. To those interested in the growing of ramie, it should prove a very useful guide, and its publication should help in the fulfilment of the author's desire to see this plant cultivated much more extensively. A.G.D.

"Artificial Resins." Scheiber and Sandig. Translated by Ernest Fyleman. Sir Isaac Pitman & Sons Ltd. (pp. 447. Price, 30s.).

This book treats a difficult and little known subject with characteristic German thoroughness. Only very rarely is the translation at all difficult to follow. Various attempts are made to define a resin, but so many qualifications are put forward that the reader may be left without any specially clear impressions. Such a criticism applies to the book as a whole—its only obvious fault is that it is perhaps a little too long, and so lacks emphasis. Perhaps the best attempt defines "resins" as "natural or artificial mixtures of organic substances, which at any rate originally possess the properties of solubility, of softening gradually, of fusibility, and also of separating from solutions in suitable solvents, on evaporation of the same, in the form of films." The authors consider that resins resemble solid solutions—"resinoid amorphism usually occurs in lyophilic mixtures, the constituents of which possess a more or less marked degree of mutual solubility." The chief classes of artificial resins are the coumarone resins, the aldehyde resins, and the phenol-formaldehyde resins, together with the urea formaldehyde products, which have a small but rapidly increasing importance. The pure scientist could benefit from the chapters on theory of crystallisation, and from the very full treatment of condensation and polymerisation reactions. The technician can also find much of interest in the book; the actual processes of resin production, with their rather unusual encouragement of side reactions so as to produce a mixed product having the nature of a solid solution, are described in as much detail as commercial reticence will permit. A most imposing list of the practical uses of resin products is given. As one might expect at the price, the book is well printed on excellent paper, and is well bound. S.M.N.

Die Künstliche Seide. By Dr. K. Süvern. Published by Julius Springer, Berlin. (642 pp., 74.5 R.M.).

This book is an addition to the fifth edition and covers a period from 1926 to 1928. The arrangement of the book is essentially the same as that adopted in previous editions. The first section of the book deals with the manufacture of artificial silk, sub-section (*a*) deals with the manufacture of nitrocellulose and its solutions, spinning processes, denitration processes. and methods of recovering the solvents. Sub-section (*b*) deals with the manufacture of artificial silk from non-nitrated plant products and is again divided into sections.

(1) Deals with preparation of cuprammonium solutions of cellulose coagulation by acids and alkalis, and recovery of chemicals.

(2) Deals with zinc chloride solutions of cellulose.

(3) Deals with viscose and gives extracts from the large number of patents taken out during the period under review. The various improvements in technique of viscose silk spinning are dealt with, also the various processes for the manufacture of viscose silk of strength above 2 g. per denier.

(4) Deals with solution of cellulose in caustic alkalis.

(5) Deals with the manufacture of cellulose esters and ethers, including new derivatives of cellulose xanthogenate containing combined nitrogen. The various processes of dry and of wet spinning are described, also the various finishing processes.

Sub-section (*c*) deals with manufacture of artificial silk from animal matters, plant gelatines, and artificial resins. Sub-section (*d*), which is the largest in the book, deals with general improvements in the artificial silk industry, methods of preparing cellulose, special solvents for cellulose, filtration plant, spinning pumps of various kinds, spinning jets and machinery in general. Manufacture of matt or dull lustre artificial silk, various finishing processes, and machinery used for the same. Sub-sections (*e*) to (*k*) deal with artificial hair, straw, artificial cotton and wool, and staple fibre. The second section of the book gives abstracts of a few patents on the uses of artificial silk. A useful index, with list of patents and references is given at the end. As this book deals with what is perhaps the most important period of development of artificial silk, it is a book the artificial silk chemist can scarcely afford to be without. W.H.

Der Aufbau der Hochpolymeren Organischen Naturstoffe. By Kurt H. Meyer and H. Mark. Published by the Akademische Verlagsgesellschaft, Leipzig, 1930 (vii + 265 pp. Price in England 18s.).

This is a work of fundamental importance to the textile chemist. It is the first complete summary of the very numerous investigations that have been made, *nearly all within the past decade*, of the structure of synthetic and natural polymers. The first 80 pages deal with the various methods of approaching the problem. Assuming an elementary knowledge of the principles of X-ray analysis, the authors explain carefully their application to the case of highly polymerised substances, and show how a critical study of lattice spacing, and of the energy relationships involved, enables one to discriminate clearly between the respective rôles of principal and cohesion (Van der Waal's) forces in the building up of such compounds. On the chemical side this introductory section contains a very good summary of the production and investigation, by Standinger in particular, of a variety of synthetic polymers from substances of low molecular weight. The authors emphasise the very important fact that these products—and presumably the natural polymers also—are never obtained as chemical individuals, but are mixtures of molecules representing varying degrees of polymerisation—hence the caution necessary in drawing conclusions about them from analysis or molecular weight measurements, and the need for collating results from every possible field of work. The next 80 pages or so are devoted to cellulose. The authors discuss critically the chemical and physical evidence from which a knowledge of its structure is being developed. The only question with which one feels they might have dealt rather more fully is that of the existence and dimensions of the crystallites, or micellæ, which they regard as secondary units in the cellulose structure. Here however, as the authors point out, the data lack precision. The structure of various cellulose derivatives is dealt with briefly, and the effects of mercerisation and other treatment upon the mechanical properties of the fibre are discussed in the light of structural data. The technologist may regret the very small space devoted to cuprammonium-cellulose, but so little is really known about it, despite the work of Hess and Trogus, that a fuller treatment can hardly be expected in a work of this nature. The book contains also chapters upon starch, rubber, and the proteins, and concludes with an interesting and suggestive excursion into the realms of cytology and the mechanism of muscular contraction. It is well printed, and contains some good diagrams and particularly fine reproductions of X-ray photographs. There is a bibliography of 346 references, unfortunately neither in alphabetical nor chronological order. Of these, it may be noted, only about 30 are from British sources, although full credit appears to have been given to workers outside Germany. W.A.S.

Kunstseide. By O. Faust. Verlag Theodor Steinkopff, Leipzig, 4th and 5th Edition (pp. 268 and Index. 15 R.M.).

This book opens with a short history of the development of artificial silk, followed by an account of the chemical and physical properties of cellulose in general. Recent work, including the X-ray analysis of natural and artificial fibres is described. The fibre forming character and viscosity of the spinning solutions are dealt with, also the relation between the method of coagulation and the cross section of the resulting fibres. Theoretical data on stretch spinning are given, followed by interesting data and photographs of X-ray spectra of natural and artificial fibres. The measurement of the lustre of fibres is described, also the calculation of denier. The influence of moisture and stretching on strength and elasticity is dealt with, and interesting points on the dyeing of artificial silk are given. The swelling properties of cellulose products and their measurement are given, followed by chemical methods of distinguishing the various kinds of artificial silks. In the technical part the raw materials, pulp water, etc., are dealt with, followed by general methods of drying pulp, filtration of solutions, various spinning machines for wet and dry spinning, recovery of solvents, staple fibre spinning machines, bobbin spinning and centrifugal spinning machines for cuprammonium silk, the general arrangement of plant for spinning, washing, and other after-treatments is given, with special data concerning bleaching plant, drying machines, twisting, and reeling machines. Special sections are devoted to nitrocellulose silk, cellulose-acetate silk, cellulose-ether silk, cuprammonium silk, and viscose silk, the last in some detail. The production of artificial silk in various countries is given to the end of 1929. A useful collection of literature is given at the end of the book. In so far as this book gives up-to-date information on points not generally dealt with in books on artificial silk it forms a useful addition to the literature of the subject, and should be most useful to chemists engaged in the industry. W.H.

PUBLICATIONS RECEIVED AND PLACED IN THE INSTITUTE LIBRARY

Proceedings of the American Society for Testing Materials. Thirty-third Annual Meeting, June 1930.

Part I contains the Annual Address by the President, T. D. Lynch, Committee Reports (D 13 on Textile Materials), and Tentative Standards, either revised or published for the first time, those relating to textiles being- D 316-30 T, Chafer Tire Fabrics; D 276-30 T, Identification of Textile Fibres; and D 123-30 T, Terms relating to textile materials.

Part II contains technical papers read at the meeting, with discussions. E. Freedman read a paper on "The Thermal Transmission of Fabrics," and W. E. Emley one on "Aeronautical Textiles"

Imperial Wool Research Conference, 1930, London, Leeds, and Edinburgh. Report of Proceedings. Published by the Empire Marketing Board. Price 1/- nett.

This contains a full report of the Proceedings of the Conference and papers read thereat.

Imperial Institute: Annual Report, 1930. By the Director, Sir William Furse, K.C.B., to the Board of Governors. Price 2/- nett.

This document records the work of the Institute and covers the Plant and Animal Products Department; the Mineral Resources Department; the Library; and the Exhibition Galleries. Particulars are given of the meetings of the Committees on Silk, on Vegetable Fibres, and on Animal Fibres. Investigations are reported on Sunn Hemp, Wool (fleeces from Iraq and Meraisi-Beladi), and rope fibres and their resistance to the action of sea-water.

The National Physical Laboratory. Report for the Year 1930. Published by the Department of Scientific and Industrial Research. Price 12s. 6d. nett.

The report of the Executive Committee and reports of the various departments are included. Those of the X-ray and Optical Departments are of interest, as also are the reports of work on Photometry.

Silk and Rayon Directory and Buyers' Guide of Great Britain. Published by John Heywood Ltd., Manchester. Price 21/- nett.
This is the seventh issue of a Directory that is now well known. Its increased size is a measure of the development of the rayon industry.

Style for Men. Directory of Trade Marks and Trade Names, 1931. Published by the National Trade Press, Ltd., London.
This volume contains 3,500 trade marks and has a classified index to advertisers.

Report of the British Association for the Advancement of Science, Bristol, 1930.
The usual annual report of the Association, embodying the Presidential and Sectional-Presidential addresses.

Department of Scientific and Industrial Research. Annual Report 1929-30. Published by H.M.S.O. Price 3/6 nett.
Contains specific references to the work of the Cotton, Wool, Linen, Silk, and Launderers' Industries Research Associations.

Medical Research Council: Eleventh Annual Report, to 30th June 1931. Published by H.M.S.O. Price 1s. 6d.
Contains an account of the research work now being carried out in problems of Industrial Physiology and Psychology. A list of publications already issued is given and special reference made to an investigation into sickness among card-room operatives.

British Economic Mission to the Far East, 1930-31. Published by H.M.S.O. Price 1/- net.
This is the report of the Cotton Mission.

Empire Cotton Growing Corporation. Report of the Administrative Council of the Corporation submitted to the Tenth Annual General Meeting, 20th May 1931.
Deals with Empire Cotton Growing (except in India) during the previous twelve months, and gives a table of crop production.

British Cotton Growing Association. Twenty-sixth Annual Report, twelve months ending 31st December 1930.
Deals with the activities of the Association and results in cotton growing throughout the period.

Insect Pests in Textiles and the Eulan Mothproofing Processes.
Reprint of a lecture given by C. O. Clarke (Associate) at the University College, Nottingham, November 1930.

"Statistical Methods for Forecasting Raw Cotton Prices." Price, 1/2 post free.
Reprint of an article by W. H. Slater, B.Sc. (Associate), in the *Textile Recorder*, January-March 1931.

"Kapok." By H. L. Williams. 72 Oxford Street, London.
A well-illustrated booklet describing this fibre and its uses.

Imperial Chemical Industries Limited. I—Basic Colours, and II—Thionol Colours.
Loose-leaf books containing mounted yarns, straws, raffia, etc., demonstrating the use of the colours made by the I.C.I.

Worsted Machinery and Woollen Machinery Catalogues. Issued by John Hetherington & Sons Ltd., Manchester.

"Modern Uses of Conveyors in Industry." A catalogue of their productions issued by Herbert Morris Ltd., Loughborough.

Improved Continuous Curling Machine. A catalogue illustrating and describing a new machine marketed by Thomas Broadbent & Sons Ltd., Huddersfield.

"Price Equivalent Tables per Yard and Metre." Compiled and issued on stout card by Kingston's Translations Institute, Leadenhall Street, London.

B.T.L. Monthly Bulletin. Issued by Baird & Tatlock (London) Ltd. The first issue of a new "House" publication.
Contains an article on "Applications of the Thermionic Valve."

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PROCEEDINGS

STANDARDISATION OF KNITTING TERMS

By J. Chamberlain F.T.I.

The rapid growth of the knitting industry has led to a bewildering, and in some cases contradictory, application of terms, so that an adequate standardisation by some authoritative body is essential. Spinners, manufacturers, knitting machine builders, wholesale and retail houses, patent agents, and, last but not least, the purchaser of knitted goods, would welcome any action which would allay suspicion and tend to broaden markets. Quite recently the National Federation of Hosiery Manufacturers has defined the meaning of a few terms used in the trade for knitted garments, but no attempt has been made to classify and standardise the names of the innumerable stitches, fabrics, yarns, machine parts, etc., used in making these garments.

In different parts of Great Britain different terms are used for similar operations, stitches, etc., and in some cases the same term is used for two entirely different operations, *e.g.* in the Midlands the term "finishing" is applied solely to those processes, wet or dry, which are carried out on fabrics or garments after they have been completed, whereas in certain parts of Scotland the term is used for the cutting out, seaming, and attaching of parts so as to make a complete garment ready for sale. These operations are known generally as "making-up." Again, the operation of joining two rows of knitted stitches in the "course" is known as "turning-off" in Nottinghamshire, "linking" in Leicestershire, and "looping" in the U.S.A. "Binding-off" and, in the case of closing the toes of seamless hose, "toeing" are other terms used for the same operation.

Another reason why some form of standardisation of terms is desirable, is to obviate difficulties in connection with the appointment of suitable operators, mechanics, etc. Labour Exchange officials, manufacturers, and machine builders are constantly in doubt as to the exact experience of applicants, and consequently there is further doubt as to the exact positions they are qualified to fill. To facilitate the choice of suitable applicants, I have recently classified operations and machines for the benefit of the local Labour Exchange. The standardisation of terms, however, cannot be effected by an individual, but by a representative body which represents all phases of the knitting industry. In order to arouse the interest of the members of the Textile Institute, however, I should like to show how absurd the present position is, first, by quoting a Gilbertian case which actually happened in Leicester a few years ago, and, secondly, by taking a few typical examples of the confusion arising from a lack of standardisation of terms.

An improved form of calendering machine was introduced by a local firm. Satisfactory prices were fixed, but a "strike" lasting some weeks resulted owing to two rival trade unions being unable to decide whether the operation was "trimming" or "finishing"!

CONFUSION OF TERMS IN KNITTING

In some districts the knitting industry is divided into sections in accordance with the types of garments produced, viz. knitted footwear, underwear, and outerwear. On the other hand, the term "hosiery" is often used in a generic manner, and when Kelly, in 1850, introduced the manufacture of knitted outerwear to Leicester, the makers of such garments styled themselves "fancy hosiery manufacturers," although they did not make hose or half-hose, and the term is still used to-day.

Originally knitted goods were of a coarse character—like hand knitting—and when finer fabrics were made, a most contradictory term was introduced, viz., "woven hosiery." This term is still used and "woven" underwear merely indicates knitted underwear with a fine stitch. Indeed, a company was formed with the title "The Woven Hosiery Co." who produced nothing but knitted fabrics.

Again, although the original term "wrought" has given way to the term "fashioned," it has become necessary to introduce the term "full-fashioned" as shaped garments which are not "wale-fashioned" are sold as "fashioned" goods. In the U.S.A. the trade has now standardised the terms "full-fashioned," "fashioned," and "shaped."

Hosiery Yarn Terms—I do not pretend to understand what is meant by the "quality of a top," and leave this term, cheerfully, to other authorities, but terms like "lambswool," "merino," "llama," "cashmere," "botany," are used for yarns quite indiscriminately and in no way represent the materials used. Other terms such as "hosiery twist," "lisle thread," "cordon," are delightfully indefinite, whilst garments are frequently stamped "wool" although containing only 5% of wool. Other manufacturers stamp hosiery "wool and cotton" when a similar percentage of wool is used, whereas for export it is essential to use "cotton and wool" if the cotton predominates. "Plated" (often erroneously spelt "plaited") goods contain varying percentages of the yarns used and, unless the percentage is given, no information is obtainable without a chemical or physical test.

Stitch Definition—Knitted fabrics, at present, are divided broadly into two groups, viz.—(1) Ordinary knitting, often called weft knitting, stockinette (British), Balbriggan, Jersey cloth (U.S.A.), etc., and (2) warp knitting, the former being a replica of hand knitting and the latter of crocheting. As a knitted fabric is composed of lateral and longitudinal rows of loops definitely known as courses and wales, perhaps a better definition for ordinary knitting would be "course knitting," i.e. knitted in courses, and "wale knitting," knitted in wales, instead of warp knitting, as the terms warp and weft indicate straight threads, and straight wefts and warps are both used as well as knitted wefts and warps. A clear line of demarcation would then be possible with sub-divisions, such as—

(1) Course knitting—(*a*) Flat—(*i*) Full-fashioned; (*ii*) Fashioned.
(*b*) Tubular—(*i*) Straight; (*ii*) Twelve-course spiral (for 12 feeders); (*iii*) Fashioned.

(2) Wale knitting—(*i*) Single warp; (*ii*) Double warp (lap defined).

(3) Combined wale and course knitting.

(4) Course knitting with weft and/or warps (straight weft and/or warps).

(5) Wale knitting " " " " "

Ladderproof Fabrics—At present the term "ladderproof" is used for fabrics possessing very varying degrees of the non-laddering properties. Plated hose (rayon and mercerised cotton) are often stamped "ladderproof" although composed solely of course knitting. Similarly, a 1 × 1 crossed float-stitch, i.e. float odd, knit, float even, knit, is also called "ladderproof" as well as other fabrics, because the laddering tendency is diminished but by no means removed. Again, although wale knitting (double warp) may be made absolutely ladderproof, this

again is dependent on the manipulation of the warps or "lap." Combined course and wale knitting again may vary in the degree of ladderproof quality, and up to the present no standard test has been made or authorised.

Fancy Fabrics—Here again there is a hopeless confusion of terms at home and abroad. A knitted "lace" fabric may be made by transferring loops, tucking, drop-stitch, cross-plate float-stitch, pelerine stitch or enlarged sinker loop, etc. The term "float-stitch," quite correctly, I believe, has replaced "press-off" work—which is only made on hand and rotary frames. "Knop" work may be tuck (plain or rib), held-stitch, stitch transfer, or made from slub yarn. Cardigans (originally made with the full-cardigan rib-stitch) are made from many different stitches. Purl knitting is often erroneously called "pearl" knitting. Half-cardigan rib is known in Leicester as "Royal rib" and full-cardigan as "polka," whilst terms like French tuck, French welt, Derby rib, Richelieu rib, can only be defined by a few privileged persons. In short, the time has come when terms shoud be more than ornamental, more than deceptive, and should possess a definite significance.

Wale Knitting (Warp Knitted Fabrics)—In this section the terms are hopeless. "Tricot," the French equivalent for course knitting (plain weft knitting), is commonly used for 1 × 1 wale knitting (warp knitting), and further defined as "single tricot" (one series of warps), "tricot or double tricot" (two series of warps), "half tricot" (two series of warps making 1 × 1 and 2 × 1 laps respectively). The latter is more often known as "locknit"—or variations of the same—owing to its positive non-laddering properties. Such terms as "elastic scarf stitch," "knock-off laps," "fall-plate work," "gimps," "shell designs," "superimposed designs," admit of various definitions. "Atlas" may be "single atlas," which will easily ladder, or "double atlas" (non-laddering) and of any traverse. Endless traverse may be called traverse warp and Milanese, and so on indeterminably.

Knitted Garments—Although in the trade the terms ladies' hose, men's half-hose, and children's socks are standard, the shopkeeper sells silk stockings (hose), men's socks (half-hose), and the trade uses the term socks, invariably spelt "sox," for children's knitted footwear only. Men's knitted "shirts" become men's vests when placed on sale. Underwear for ladies becomes "lingerie." Sports hose become cycle hose, shooting hose, golf hose, etc., according to the purchaser's appearance. Women's single-piece underwear garments are known as combinations or "combs." whilst a similar garment for men is known as a union suit. I could quote many other examples, but the above are quite sufficient to show the confusion which exists.

Knitting Operations—Mention has been made of the various names for "linking," but there are many other terms which are similarly confounding. The term "top-head" is used for ordinary circular and flat rib-knitting machines, and for both plain and ribbed "fancy" top machines, about which the ordinary "top-head" operator knows nothing. On the other hand, timid operators often refuse to operate similar machines possessing different names. Thus, "X.L.," "Simplex," "X-L-sior," "Komet," "Auto-Swift" machines fall naturally into one group from the operating point of view, as all are super-imposed cylinder machines for making seamless ribbed hose and half-hose or socks, yet operators will say "I can only work so-and-so machines." Knitting machines should be grouped fundamentally, as a "full-fashioning legger" operator requires a totally different training from a seamless hose machine operator, or a jacquard flat machine hand. Yet all are called "hosiery hands," and little wonder that the Exchange officials are bewildered.

Knitting Machine Terms—Here again is a hopeless confusion and contradiction of terms. No ordinary mechanical engineer would call a triangular piece of steel a "cam." The parts on a knitting machine which give rise to the movements of needles, sinkers, jacks, sliders, etc., are definitely and, by common usage, rightly known as cams, but when a disc or a straight piece of metal is known as a "cam" (rest "cam," filling-in "cam") it seems as if license has been exceeded.

Further, the "cam" which forms—by aid of the needle or sinker—the loops is known as "slur-cock" (cotton frame, hand frame, etc.), "stitch cam" (circular machines), "tension" or "lock" (flat machines), "knock-over" (rib machines), etc. Terms like sinker, jack, slider, propeller, are all used for one part on double-cylinder or double-bed machines, whereas needles, sinkers, jacks, points, all have their special functions and could be properly defined. To overcome the many difficulties, most machine builders prefer, quite logically, to illustrate and number parts in preference to naming them, but this only partially solves the problem of nomenclature. Parts are invariably called by one name in patent specifications and by many others in the works. Moreover, patent agents rarely use the same term for the same part or function. This undoubtedly has its effect when the claims reach the Patent Office, and is a further example for the need of standardised terms.

Finally, there is the question of the advisability of allowing foreign terms to replace British terms, e.g. "intarsia" has replaced "solid," "links and links" is used instead of "purl work," "knop" has been substituted for "knob." American terms are constantly being substituted for older and, in some cases, far more expressive British terms, e.g. spring needle for bearded needle, bur for bladed wheel, cut for gauge. As all the fundamental inventions were of British origin, it does not seem appropriate to adopt foreign names without forethought. Possibly there are persons who think the "spring" needle and "spring needle hosiery" are U.S.A. improvements on the old British bearded needle and bearded needle hosiery, whereas the spring needle is a bearded needle, unaltered.

CONCLUSIONS

(1) It is submitted that there is a great need for the standardisation of terms used in the knitting industry, as this has been openly expressed by patent agents, machine builders, manufacturers, agents, and others connected with the industry, as well as by members of the general public.

(2) Clearly the question can only be solved by collective action, as no one individual could hope to define all the terms used to the satisfaction of those engaged in the many branches of the industry.

(3) An authoritative committee, working through some recognised professional body, such as the "Textile Institute," would be far better than a committee formed by a federation of manufacturers, who only represent one phase of the industry.

(4) Such a committee could include representatives of manufacturers, merchants, machine builders, trade unions, educational authorities, patent agents, textile societies, and members of allied industries, e.g. spinning, dyeing.

(5) The committee could work in co-ordination with other similar committees who are endeavouring to standardise terms in other branches of textiles.

NOTES AND NOTICES

Institute Examination

The next Institute examination in General Textile Technology has been fixed to take place on Wednesday, the 9th December 1931. The examination is open only to applicants for the Associateship whose qualifications are such that the Selection Committee can admit them to this examination, the passing of which completes the requirements of the regulations governing Associateship awards. It has become customary to hold the examination in various centres simultaneously, according to the location of the respective candidates. For the next examination, the arrangements contemplated are more far-reaching than previously, as candidates located in India, South America, and South Australia have to be provided for. If the arrangements are carried out the occasion will be the first on which Institute examinations has taken place abroad.

Institute Scholarships

Following the special grant to the Institute, in 1928, by the Cotton Reconstruction Board and the Trustees of the Cotton Trade War Memorial Fund, the Scholarship scheme of the Institute, which became operative in the latter part of 1930, may be said to be giving promise of quite successful application. The annual income from the investment of the fund has been devoted to the maintenance of one scholarship, since October 1930, and, by the time this *Journal* is issued, a second award will have been made. Thus, award of a scholarship covering three years of special training, with maintenance allowance to the holder, has been effected in two successive years. The income available is not sufficient to provide for annual award, and the time of award of a third scholarship will depend entirely on the availability of income for the purpose. A report as to the scheme and as to the progress of the first scholarship holder was mentioned at the last meeting of the Council of the Institute when general satisfaction was expressed in regard to the records presented. The scholarship takes the form of a special course of two years at a technical college, to be followed by one year of experience abroad. A complete report is to be presented to the October meeting of the Council.

Section Meeting Arrangements

Committees concerned with arrangement of meetings in connection with the various Sections of the Institute have, for the most part, carried out a good deal of preliminary work in regard to their respective programmes. In the case of the Midlands Section, the programme for the coming session was almost completed at the last meeting of the Committee, and the lectures and visits to works provided for should prove most interesting. The London Section's prospects as to meetings are regarded as satisfactory, whilst the Lancashire Section arrangements are proceeding. It is unusually difficult, in existing circumstances, to complete arrangements in advance for meetings covering a whole session. The Lancashire Section Committee has decided to confine attention to more immediate requirements, and two meetings have already been definitely arranged for the latter part of this year. Only the actual date and time of commencement now require arrival at agreement in respect to two Papers to be contributed. One of these, which will probably be fixed for November, is likely to prove of special interest as the subject will have a direct bearing on the extended use of cotton materials for industrial purposes. The lecturer will deal with the subject of "Cotton Textiles for Electrical Insulation" Announcements will follow in due course.

Prizes for Woven Cotton Fabrics

The awards for 1931 in the Lancashire Education Committee (Higher Education) annual competitions for collections of woven cotton fabrics, produced by students at technical institutions in the county area, are announced as follow—

Gold Medal and £10—Arthur Mutton (Burnley Municipal College).

Silver Medal and £10—Lewis Sutcliffe (Nelson Technical School).

Prizes of £10 each—Eric Basnett (Radcliffe Technical School), Norman Bank (Colne Technical School), and William Pickles (Colne Technical School).

Prizes of £5 each—Robert Harwood (Darwen Technical School), Fred Lansdale (Radcliffe Technical School), James Settle (Radcliffe Technical School), and Rennie Wrigglesworth (Nelson Technical School).

The adjudication was carried out by the Competitions Committee of the Textile Institute. This Committee's report on the competition is as follows—

"The Committee desire to express their keen sense of appreciation of the satisfactory level of attainment reached by competitors generally. Most of the albums provide evidence of sincere and determined effort, reflecting credit on both

competitors and schools. In the latter connection, indeed, it is felt that the influence of the operation of the competition is of incalculable benefit to all concerned. In this year's competition, particularisation as to the structure of the fabrics has been well carried out, and the Committee is pleased to be able to report the registration of a high average of marks in respect of the costing of cloths. Some amount of weakness persists, however, so far as classification is concerned, and future competitors would be well advised to give more attention to the requirements in respect of fitness for purpose. Too often, the impression arises that classification may have been considered subsequent to rather than at the outset of production of the cloth, and that such proceeding has inevitably led to unsatisfactory classification along with unsuitable colour selection. Careful choice of suitable yarn for a particular cloth, followed by experiment with regard to the most desirable particulars, weave, and colour, together with constant attention to the purpose for which the fabric is intended would be much more likely to yield a better result.

The Committee offers suggestions as to revision of the scheme and conditions which it is hoped may be acceptable. In proposing the addition of a Single Specimen Competition, the Committee is only actuated by a desire to extend the scope of the competition, and in this way to bring the competition into line with other schemes of similar character."

Textile Institute Diplomas

Election to Associateship has been completed since the appearance of the previous list (August issue of this *Journal*), as follows—

ASSOCIATESHIP

KIRKWOOD, Robert Edwin Alexander (Lurgan, N. Ireland).

Institute Membership

At the September meeting of the Council, the following were elected to membership of the Institute—Prof. H. J. Ball, S.B., B.C.S., Lowell Textile Institute, Lowell, Mass., U.S.A. (in charge of Textile Engineering Department); Geo. Bancroft, 102 Market Street, Thornton, Bradford (Warehouse Manager); Wm. Brown, M.Sc. (Leeds), A.I.C., 32 Craignair Road, Tulse Hill, London S.W.2 (Works Chemist and Manager); A. Crawford, K.C., M.A., LL.B., Bank Buildings, 16a St. James's Street, London, S.W.1 (Chairman, Scottish Flaxspinners' and Manufacturers' Asscn.); E. Dewhirst, 24 Ash Mount, Great Horton, Bradford, Yorkshire (Foreman Overlooker); C. S. Edwards, American Consulate, 47 Market Street, Bradford, Yorkshire (American Consul); M. C. Ghia, 24 Elphinstone Circle, Fort, Bombay, India (Merchant and Partner); G. Greenwood, Darnley Square, Kaiapoi, New Zealand (Works Manager); Emil Honegger, 85 Susengergstrasse, Zurich 7, Switzerland (Professor, Eidgenossische Technische Hochschule); O. Jackson, Hillhead, Cullybackey, Co. Antrim, Ireland (Works Manager, Bleach and Dyeworks); Y. S. Mirza, 57 Mirza Building, Nusserwanji Petit Street, Bombay No. 7, India (Examiner of Stores).

REVIEWS

Die Polysaccharide. By Hans Pringsheim. Third edition. Published by Julius Springer, Berlin, 1931 (viii—393 pp. Bound, 26.80 RM.).

The considerable advances which have been made in sugar and polysaccharide chemistry since the publication of the second edition of this work (1923) have necessitated a practically complete rewriting and a very considerable enlargement for the third edition. This embodies the literature published up to February 1931. The book is divided into two parts, of which the first (60 pages) deals with the simpler, readily crystallisable sugar-like di- and tri-saccharides (maltose, cane sugar, etc.). Following an account of the classification and nomenclature, the methods of research which have been employed in elucidating the constitution

of these bodies, and also methods of synthesis, are discussed. The second part of the book is devoted to the class of complex polysaccharides of which cellulose and starch are typical members. This part is divided into ten sections. Section I (36 pages) deals with cellulose, its occurrence, properties, and chemical degradation. In connection with this last subject it would have been useful if fuller reference had been made to recent textile-chemical investigations, particularly those of Clibbens and his co-workers. The next section gives an account of the so-called incrusting substances which are found in association with cellulose in various plant tissues (lignin, hemicellulose, etc.). Section III deals with the microbiological degradation of cellulose and its rôle in soil chemistry, while the next section deals with degradation by ferments and the digestibility of natural products which contain cellulose. Sections V and VI (43 and 29 pages) are devoted to starch and glycogen, their occurrence, properties, and chemical and fermentative degradation. Section VII deals with dextrine and similar bodies and Section VIII with inulin, hemicelluloses, chitin, etc. Finally, there are two sections dealing particularly with problems of constitution, the former devoted to general methods and principles and the latter to the constitution of particular polysaccharides, more especially starch and cellulose. In these chapters, *inter alia*, the X-ray spectrographic method of investigation is considered, together with the various methods by which the molecular complexity of highly polymerised compounds has been examined during recent years. In dealing with cellulose and starch very full references are made to investigations which have been made in countries outside Germany but with pectin and hemicelluloses, and to a certain extent with lignin, we miss a number of references to the English and American literature. In particular, one expected to find a mention of the work of Schryver and others on pectin and of O'Dwyer, Norris, Mehta and others on hemicellulose and lignin. There is also no reference to Sucharipa's work on pectin. As a summary and critique of the very extensive literature relating to polysaccharides this new edition should prove of very considerable value to those whose interests are in this field. Very few typographical errors were noticed, but in the volume sent for review a portion of the Table of Contents has been omitted. C.R.N.

Jute and Linen Weaving. Part I—Mechanism, and Part II—Calculations and Structure of Fabrics. By Thomas Woodhouse, F.T.I., formerly of Dundee Technical College and School of Art, and Thomas Milne, formerly of Dunfermline Textile School. Second edition. Published by Macmillan & Co. Ltd., London. (Part I, 582 pp. and index, 15/- nett, and Part II, 201 pp. and index, 7/6 nett.)

Although the second edition of Part I of the above work appeared as long ago as 1914, an oversight on the part of the publishers prevented any reference to the book being made in the columns of this *Journal*. The appearance of a second edition of Part II renders the present moment opportune for a brief review of both volumes.

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competitors and schools. In the latter connection, indeed, it is felt that the influence of the operation of the competition is of incalculable benefit to all concerned. In this year's competition, particularisation as to the structure of the fabrics has been well carried out, and the Committee is pleased to be able to report the registration of a high average of marks in respect of the costing of cloths. Some amount of weakness persists, however, so far as classification is concerned, and future competitors would be well advised to give more attention to the requirements in respect of fitness for purpose. Too often, the impression arises that classification may have been considered subsequent to rather than at the outset of production of the cloth, and that such proceeding has inevitably led to unsatisfactory classification along with unsuitable colour selection. Careful choice of suitable yarn for a particular cloth, followed by experiment with regard to the most desirable particulars, weave, and colour, together with constant attention to the purpose for which the fabric is intended would be much more likely to yield a better result.

The Committee offers suggestions as to revision of the scheme and conditions which it is hoped may be acceptable. In proposing the addition of a Single Specimen Competition, the Committee is only actuated by a desire to extend the scope of the competition, and in this way to bring the competition into line with other schemes of similar character."

Textile Institute Diplomas

Election to Associateship has been completed since the appearance of the previous list (August issue of this *Journal*), as follows—

ASSOCIATESHIP

KIRKWOOD, Robert Edwin Alexander (Lurgan, N. Ireland).

Institute Membership

At the September meeting of the Council, the following were elected to membership of the Institute—Prof. H. J. Ball, S.B., B.C.S., Lowell Textile Institute, Lowell, Mass., U.S.A. (in charge of Textile Engineering Department); Geo. Bancroft, 102 Market Street, Thornton, Bradford (Warehouse Manager); Wm. Brown, M.Sc. (Leeds), A.I.C., 32 Craignair Road, Tulse Hill, London S.W.2 (Works Chemist and Manager), A. Crawford, K.C., M.A., LL.B., Bank Buildings, 16a St. James's Street, London, S.W.1 (Chairman, Scottish Flax-spinners' and Manufacturers' Asscn.); E. Dewhirst, 24 Ash Mount, Great Horton, Bradford, Yorkshire (Foreman Overlooker); C. S. Edwards, American Consulate, 47 Market Street, Bradford, Yorkshire (American Consul); M. C. Ghia, 24 Elphinstone Circle, Fort, Bombay, India (Merchant and Partner); G. Greenwood, Darnley Square, Kaiapoi, New Zealand (Works Manager); Emil Honegger, 85 Susengergstrasse, Zurich 7, Switzerland (Professor, Eidgenossische Technische Hochschule); O. Jackson, Hillhead, Cullybackey, Co. Antrim, Ireland (Works Manager, Bleach and Dyeworks); Y. S. Mirza, 57 Mirza Building, Nusserwanji Petit Street, Bombay No. 7, India (Examiner of Stores).

REVIEWS

Die Polysaccharide. By Hans Pringsheim. Third edition. Published by Julius Springer, Berlin, 1931 (viii—393 pp. Bound, 26.80 RM.).

The considerable advances which have been made in sugar and polysaccharide chemistry since the publication of the second edition of this work (1923) have necessitated a practically complete rewriting and a very considerable enlargement for the third edition. This embodies the literature published up to February 1931. The book is divided into two parts, of which the first (60 pages) deals with the simpler, readily crystallisable sugar-like di- and tri-saccharides (maltose, cane sugar, etc.). Following an account of the classification and nomenclature, the methods of research which have been employed in elucidating the constitution

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structure, while easy reference is facilitated by the addition of a good index. For the sake of those unacquainted with the former editions, it may be mentioned that Part I is divided into 22 chapters dealing with yarn counts; reeling, bundling, and setting; warp winding; weft winding; warping, beaming, and dressing; drawing-in, reeding, and weaving; shedding; tappet driving and setting; supplementary shedding motions; jacquards, shedding, mounting, etc.; picking and beating-up; let-off and take-up motions; box motions; auxiliary motions, such as warp protectors, weft forks, etc.; terry towel motions; automatic weft supply; selvage motions; and methods of driving looms. The lucid explanations of these practised writers are enhanced by the inclusion of 305 illustrations, mostly well-arranged line drawings and explanatory diagrams. The subject matter in Part II embraces eleven chapters covering yarn and twisted thread counts; warp and weft setts and porters; warping; warp, weft, and jute and linen fabric calculations; prime costs and analysis of fabrics; yarn diameters and their structural values; and fabric structure. In addition, there are 38 illustrations, including photographical reproductions of typical jute and linen fabrics. There is a slight overlapping in the material dealing with yarn counts, setts and porters, and if a third edition of Part I is published, the relative matter therein might with advantage be omitted. Both books will be found useful to all engaged in the textile industries and practically essential to those in the jute and linen branches. A.B.

GENERAL ITEM

Special Summer Course for Textile Teachers

The short courses for teachers in technical and other schools, promoted annually by the Board of Education, were again held during July of the present year. The course in textile subjects organised by Mr. J. E. Dalton, H.M. Inspector, took place at the Westminster Training College, London, from the 20th to the 31st July. The work in textile technology was conducted by Professor W. E. Morton, assisted by Mr. Slattery, of Manchester. The gymnasium of the College had been temporarily equipped so that facilities were available for the testing of fibres and fabrics, both by mechanical and microscopical means. Special classes in microscopy were conducted at the Chelsea Polytechnic by Messrs. Lacey and Berkeley. The course was interestingly planned and, in addition to experimental work, many special lectures were provided. Mr. F. Scholefield, of Manchester, lectured on "The Bleaching of Cotton Piece Goods"; Mr. W. A. Hanton on "Improving the Power Loom"; and Dr. J. B. Speakman (Leeds) contributed two papers on "Recent Developments in the Study of Wool Finishing Processes," with lantern illustrations; Dr. Speakman also lectured on "A General Theory of Wool Dyeing." The subject of "Teaching Methods" was dealt with in a series of three papers by Mr. J. Wilson, H.M.I., and Mr. Harold Salt, H.M.I., presided over a number of the lecture meetings. Mr. Norman Jones, of Bolton and Manchester, contributed an exhaustive paper on "The Teaching of Practical Spinning." Owing to the unavoidable absence of the author, the lecture was read by Mr. Dalton, and it was agreed that in view of the exceptional interest of the contribution to teachers of spinning, endeavour be made to secure typewritten copies for the teachers in attendance. Two or three educational excursions were arranged, including visits to the Home Office Museum, to a silk factory associated with the old Spitalfields silk weaving industry, and also to Battle Abbey and Bodian Castle. The Westminster College, with hostel facilities, provided an excellent centre for the special course, and the teachers in attendance pursued their studies and experimental work with marked enthusiasm. Mr. J. D. Athey (General Secretary) attended as the representative of the Textile Institute, and on one afternoon contributed a short address on the Institute's qualification scheme and the regulations governing awards of the Associateship and Fellowship. Amongst occasional visitors during the period of the course were Mr. C. C. Hawkins and Col. French, of the City and Guilds of London Institute, who expressed warm appreciation of the character of the whole effort in the interests of technical education.

THE JOURNAL OF THE TEXTILE INSTITUTE

Vol. XXII OCTOBER 1931 No. 10

PROCEEDINGS

Lancashire Section

Meeting at the Geographical Hall, Manchester, Wednesday, 30th September 1931; Mr. W. T. Boothman presiding.

THE SUSPENSION OF THE GOLD STANDARD: CAUSES AND CONSEQUENCES

By G. W. DANIELS, M.A.
(Professor of Political Economy at the University of Manchester)

Whatever views one may hold as to the exact degree of imperfection with which the gold standard performs its functions, it must be apparent to all that its suspension in this country is an event of immense importance. Potentially it ranks in importance with what are regarded as the crucial events in the world's history, but whether, in actuality, the event will prove of this character no one at the moment can say. What can be said is that it is an event which, to cope with its potentialities, will make a call upon all the wisdom, foresight, and strength of character that we possess. I am not concerned to argue whether the gold standard is an imperfect standard, or that more perfect standards are conceivable, and that now we can seek a better standard, or maybe do without any definite standard at all. The pressing consideration at the moment, perhaps for many months in the future, is that, in this country, the gold standard is suspended. What does its suspension mean?

In order that my later remarks may be clear it is necessary to say a few words on the functions which the gold standard performs. The main function of the gold standard is that when a country adopts and adheres to the standard, the value of its currency is linked with the value of gold, with the consequence that fluctuations in the value of this currency are limited by the fluctuations in the value of gold. It follows, therefore, that so long as the country adheres to the gold standard anyone who possesses or has a claim on the currency of the country is virtually in the position of possessing or having a claim upon gold. The guarantee that this is the case is that if this person desires he can, by complying with the regulations governing the gold standard of the country, exchange the currency for gold. In pre-war days we could actually exchange our currency for gold coins, and under the post-war arrangements this exchangeability has held in substance though there are differences of detail. One immensely important consequence of this arrangement is, that, so long as a country adheres to the gold standard, its currency cannot be inflated in relation to gold. If inflation is threatened the result will be that the currency will be exchanged for gold, from which it follows that if a country adheres to the gold standard it must keep its currency within such limits as will ensure its exchangeability for gold. Obviously this does not mean that every item of currency must be exchangeable for gold if all these items were presented at the same time; exchangeability means that all those who desire at any particular time must be able to exchange their holdings of currency for gold. The gold standard is therefore an automatic safeguard against inflation—when a

country which has had a gold standard departs from it this automatic safeguard goes. It does not necessarily mean that inflation will take place, but the automatic protection against it which the gold standard gives has gone—the danger therefore to which this country is now exposed is the danger of inflation. In view of continental experience in recent years I do not think I need dwell on the character of this danger. One can only hope that these recent examples will be sufficient to ward off the danger. It is not sufficient, however, to recline at ease and say that inflation will never be allowed in this country. On the contrary, until we again reach smooth water, the danger will be present, and it will require constant vigilance and an immense strength of will to resist it. Of all economic poisons there is none so deceptive and destructive as inflation, but it is a poison we are not obliged to take; the essential thing is that it should not be offered.

The second large function of the gold standard has particular reference to our relations with other countries and especially to the trade which is carried on with them. From what I have said of the position of the currency of a particular country in relation to the gold standard, it will be quite clear that when other countries adopt and adhere to this standard, there must be a continuous and close relation between the values of their currencies. The practical effect is, of course, that, as between these countries, there is a definite objective basis on which trade is carried on, the basis as between the countries being given by their parities of exchange in terms of gold. So long as the countries adhere to the gold standard again the fluctuations of the exchanges are limited by their being tied to the objective standard, gold.

Apparently if the exchanges of the various countries are each linked to gold in the way I have described, their currencies must also be linked to each other in the sense that the currency of one country will have the same value—or, better, the same purchasing power as that of the others. If the purchasing power of the currency of one country falls below that of another country it is evident, seeing that they are all linked with the common standard gold, that those who possess or have claims on the currency of the country whose value or purchasing power has fallen below that of the others will seek to exchange it for the higher valued currencies—the method, if need be, being first to exchange it for gold, and then gain possession of a currency which has maintained its parity with gold. On the assumption that the country in question cannot provide the gold it means that it has failed to maintain the gold standard; its currency will not now be connected by a definite objective link with the currencies of the countries that are still on the gold standard; its currency will now be valued in relation to the other currencies by what those who hold these currencies consider that it is worth at any particular moment in terms of these currencies. These values are of course what are expressed in the rates of exchange. Under these conditions the limitation on the fluctuations of the exchanges which exists under the gold standard has gone, with the consequence that the exchanges may fluctuate widely. Trade tends to become a speculation in which large losses or gains may be made by individuals owing to the operation of forces more or less beyond their control. Under such conditions a healthy condition of trade is almost an impossibility. The centre of gravity of trade which ought to be in the future is too near the present.

This again is exactly the position of this country now that the gold standard has been suspended. Stated simply the position is that we have not been able to meet all the claims that have legitimately been made upon us to meet our obligations in gold; we have suspended the gold standard, and our currency has now to find its level in terms of other currencies at the value which is placed upon it by those who hold or have a claim upon these currencies. What this meant is that whereas when we were on the gold standard £1 was worth just over 124 French francs or 4·86 dollars, on Monday, 28th September, it was worth 98 French francs or 3·83 dollars; or stated in another way, whereas £1 in currency was worth the amount of gold in a sovereign, it is now worth the amount of gold

or of currencies based upon gold represented by about 15s. 9d. Stating the position in yet another way it means that the prices of imports which in terms of gold or of currencies still based upon gold would be £1 are on the basis of this exchange about 25s. 6d. On the other hand, it means, on the assumption that prices remained the same as before in this country, that whereas, when we were on the gold standard, it would require about 124 French francs or about 4·86 dollars to buy £1 worth of our exports, now the exports can be bought for 98 French francs or 3·83 dollars. It is evident, therefore, seeing that our imports have become dearer in terms of our own currency, and our exports cheaper in terms of foreign currencies, so long as this position holds, there will, on the one hand, be an impulse to a restriction of our imports and, on the other hand, an impulse to an extension of our exports. The relative extent to which these two impulses will operate has yet to be seen. In fact, until a stage is reached at which the relations between the various currencies become stable, any discussion of the matter may appear, from the point of view of what will actually happen, very much in the air. However, in considering the operation of the two impulses, and stating the position in academic language, much will depend upon the elasticity of the foreigners' demand for our exports in relation to the elasticity of our demand for our imports, and in this connection it is not too encouraging to find that in 1930 no less than 70% of our total imports were foodstuffs and raw materials—about five-eighths of our foodstuffs and about four-fifths of the raw materials of our industries come from abroad—while 76% of our total exports in 1930 were manufactured goods. (1930—Retained imports, foodstuffs and raw materials, £664,000,000; exports, U K. manufactured goods, £440,000,000.)

It would appear, therefore, that the elasticity of our demand for imports will probably be rather small. But we must have them; we cannot do without foodstuffs and raw materials even at the higher prices in terms of our money. Such being the case, it is evident, therefore, that, when available stocks are exhausted, and if the present position continues, a considerable rise in the prices of imported foodstuffs and raw materials is inevitable. But what of the elasticity of the foreigners' demand for our exports—mainly manufactured goods? Well, as we have seen, in terms of their currencies, if based upon gold, these exports will tend to be cheaper, but what the effect will be on the total demand it is impossible to say. Obviously an important consideration is—How much cheaper? Evidently in so far as imported raw materials enter into the exports this will be an item leading to a rise in their costs of production. On the other hand, in so far as they can be produced in larger volume, this will tend to reduce the overhead costs per unit of output. Further, in so far as the factors necessary for their production can be obtained at present prices, costs will not be increased on this account. Presumably, fixed interest costs will be lightened but, on the other hand, the fact that foodstuffs are likely to increase in price, introduces an element of doubt as to whether for an indefinite period, other factors will be obtained at present prices. It will, I think, be evident without further discussion that how far our exports will have an advantage through the lowering of their prices in terms of foreign currencies based upon gold will depend upon the extent to which the costs of production of our exports in terms of our currency are not raised above the present level. Moreover, in thinking of these costs it would be foolish to ignore the possibility that, if the pressure of our exports is felt to be too strong in foreign countries the tariff barrier may be utilised against us. However the raising of costs is occasioned, it will be clear, that to the extent to which these costs are raised, the advantage which might be derived from the exchange disappears. If these costs are so raised that this advantage disappears altogether we shall be in no better position, perhaps in a worse position, than before. It must not be imagined that a country which was regarded as the centre of the world's monetary system and trade, and whose currency was to a large extent *the* international currency, can make the departure which has been made and everything else remain the same.

To imagine this is as futile as to imagine that when a complex machine is dislocated it will perform its function as well if it is dislocated still more. It is much more likely that the suspension of the gold standard in this country with its reactions upon the already sickly state of confidence in the world will prolong rather than shorten the world depression of trade.

Again I am obliged to say we have been compelled to embark upon a venture of which no one can clearly visualise the result. Of one thing we may be quite confident. The venture is not one to call forth elation in the expectation that, in itself, it will usher in that improvement of the economic situation which has been so anxiously awaited since the conclusion of the war. In its very nature the venture cannot be a real remedy. At best it is a regrettable necessity, out of which good can come only if it compels us fully to face the facts of our position and then impels us to overcome them in the only real way; by hard persistent work, far-sighted enterprise, aided by an abundance of capital, without too much regard as to whether the reward of our efforts is as great as we think it ought to be.

The necessity for this becomes clear when we seek for the causes of the present position. Some of these causes are no doubt external rather than internal to this country; they are involved in the economic depression under which the world has suffered for the last two years. On the other hand, there are causes internal rather than external to this country, and these causes have been in operation for a much longer period. To understand the position it is essential to bear in mind that we are pre-eminently a country engaged in foreign trade. Our industrial structure has been built up and, at the present time, exists as adapted to this trade.

Generally, our manufacturing industries are much larger than would meet the requirements of the home market and, as a consequence, other industries are smaller. Already I have mentioned that about five-eighths of our foodstuffs and about four-fifths of the raw materials of our industries have to be imported. As we know in Lancashire, the cotton industry is far larger than would be needed to supply the home market. These two facts are obviously related and closely connected with them is the further fact that our trade extends to every part of the world. It is the character and extent of this trade, together with the world-wide services of British shipping and the ramifications of British investments, with a faith in the integrity of this country, that has made London the centre of the world's monetary system and trade. As you know, the finance of a very large portion of the world's trade, not merely that between this country and others, is carried on through London. Our finance industry is one of our largest industries. Essential to the satisfactory working of this industry is that, at all times, the available world credits of this country should exceed her debits. If they do not, this finance industry must be seriously affected. These credits, of course, are made up mainly of our exports of merchandise-goods produced within the country and exported—and largely of services, of which the two chief are shipping services and financial services, and, in addition, the credits on our overseas investments. The debits, on the other hand, are composed of our imports of merchandise together with similar items to those just mentioned. Normally, on balance, our world-credits have largely exceeded our world-debits, leaving a large surplus which has been the source of the country's financial strength in the world. The significant fact is that in post-war years this credit surplus, in terms of money, notwithstanding the higher level of prices, has never reached its pre-war dimensions, with the result that our position has been weaker at a time when the stresses and strains have been greater—

	1913	1924	1925	1926	1927	1928	1929	1930	1931	Average 1924-30
Surplus £M ...	181	86	54	9	114	137	138	39	—?	82

What is the explanation of this decreased surplus? Obviously it can be explained either by a relative increase of our debits, or a relative

decrease of our credits, and these debits and credits are each composed of merchandise and services. It is, of course, well known that our post-war imports of merchandise, in terms of money, have greatly exceeded our pre-war imports. Also it is true that our post-war exports of merchandise, in terms of money have exceeded our pre-war exports, but the excess has been much less than in the case of the imports. The position in this respect is indicated in the fact that whereas, in 1913, our total exports of merchandise, in terms of money, represented 83% of our total imports of merchandise, for the years 1924–30, the average has been 68 per cent. In the years 1924–30 our imports of merchandise, in terms of money, have exceeded the 1913 imports by an average of 58%, while our total exports of merchandise, in terms of money, have exceeded the 1913 exports by only 31 per cent. On the other hand, our nett shipping income in the years 1924–30 has exceeded the 1913 income by an average of 36%; while our nett income on investments, in the same years, has exceeded the 1913 income by an average of 24 per cent. Again, the nett receipts for financial services, in the same years, have exceeded the 1913 receipts by 145 per cent. Of the total of these credit items for services as distinct from merchandise, shipping income which in 1913 accounted for 28%, in the years 1924–30 accounted for an average of 27%; the corresponding figures for receipts for financial services being 7·5% in 1913, and 13% for 1924–30; investment income 62% in 1913, and 55% for the years 1924–30.

Year	Merchandise			Services			
	Total Imports	Total Exports	Exports as a Percentage of Imports	Shipping Income	Finance Income	Investment Income	Total Service Credit Items
1913	100	100	83	100 (28%)	100 (7·5%)	100 (62%)	100
1924	166	148	74	149	240	105	121
1925	172	146	70	132	240	119	130
1926	162	123	63	138	240	136	140
1927	159	131	68	149	252	136	146
1928	156	133	71	138	260	129	143
1929	160	131	69	138	260	129	146
1930	130	104	63	110	220	112	127
Average 1924–30	158	131	68	136 (27%)	245 (13%)	124 (55%)	136

On the whole our credits for services and investments have kept up better than our credits for our exports of merchandise, especially so bearing in mind the extent to which our overseas investments were depleted for the purpose of financing the war. The centre of our weakness is obviously the failure of our exports of merchandise to maintain their relative position with our imports. This failure has reacted on our shipping income, and on our income from investments, for the deficiency has meant that funds which would have been available for investment have had to be utilised to pay for our imports. The position may perhaps be seen in a clear way by some figures which show the extent to which our services and investment credits have had to be utilised in 1913 and 1924–30 to pay for the excess of our imports over our exports of merchandise, in percentages—

1913	1924	1925	1926	1927	1928	1929	1930	1931
46	79	88	98	77	72	73	91	?

What these figures show is that whereas in 1913 only 46% of the service and investment credits had to be drawn upon, between 1924 and 1930 the percentage

has never fallen below 72%, in the fateful year 1926 it increased to 98%, last year to 91%, and this year it appears that these credits may be far from meeting the excess. The present situation is thus brought to a focus.

The *immediate* cause of the present crisis which has resulted in the suspension of the gold standard is the world slump that began to appear in the latter part of 1929. This slump has found expression in a dislocation of the world's economic mechanism which was working in a very uncertain way before, largely owing to the difficulties arising from the problem of war debts and reparations and from the intensified policy of tariff barriers to trade. With the slump the working of this mechanism has slowed down and accentuated difficulties already present. Certain countries were in a position of exceeding instability and, with the slump, they have been brought to the verge of collapse and world confidence has been shaken. No matter how strong the position of this country as a centre of world finance and trade had been, its strength would have been severely tested. At a time when we needed larger world credits in relation to our debits, these credits have been reduced by the world slump—it has deleteriously affected the nett income of our services and investments, which on the whole have shown good progress in recent years, and it has made still worse the relative position of our exports of merchandise, a position which, in fact, was tending to become worse even before the world slump appeared.

Such are the causes which I mentioned as being external rather than internal to the country. But now for the causes which are internal rather than external to this country. In the first place it is of the very greatest importance that we make no mistake about this fundamental fact that the industry and trade of this country were in a state of depression, with a vast army of unemployed, before the world slump. Of the world generally this is not true. The world generally was forging ahead, so much so that it is estimated that world trade in 1929 exceeded pre-war world trade by some 25 per cent. During the same period our trade diminished by about 13 per cent. It is this diminution in our trade, while that of the world increased, which is the vital consideration for the people of this country. What is the explanation? All I shall do is to give some figures which are food for thought—

	Total Imports		Exports U.K. Produce and Manufactures	
	Average Values	Volumes	Average Values	Volumes
1913	100	100	100	100
1924	155·0	107·4	188·9	80·1
1929	133·6	119·0	160·0	86·8
1930	117·3	116·0	152·7	71·0

What these figures mean is that in 1913 a person with £100 could purchase a composite unit of imports or U.K. exports. In 1930 this person would have to pay £117 3s. for the imports and £152 7s. for the exports, and so for the other years. While we recognise the existence of causes over which we have little control, may not this be the supreme explanation of our relative position, of why our volume of imports is what it is, and our volume of exports what it is? Are we to suppose that our position would have been what it has been in post-war years, and is now, if the disparity between the prices at which we have supplied our exports and the price at which our imports have been supplied had been less? It is hard to suppose that. If we cannot suppose it, it means that not only to recover something of our former position, but to maintain it as it is at present, this disparity will have to be lessened. Prices we know are related to costs.

It would appear, then, that if this country is to continue to maintain even its post-war position in world trade, these costs will somehow have to be reduced to bring them into relation with world costs. If, on the other hand, it should prove that these costs cannot be reduced, so as to give appropriate prices; if no large recovery is possible with our present industries; if the world has permanently ceased to buy from us those products which our industrial structure has been adapted to produce; the only alternative is to recognise the fact, and seek to adapt our industrial structure to other branches of activity which will find employment for our capital and labour, and resign ourselves to the standard of living which these branches of activity will yield. The large fact, which is so obvious that I need not emphasise it, is that we have reached a critical stage in the social, economic, and political history of this country, a stage which will require all the wisdom, skill, determination, and power of sacrifice we possess to overcome it.

In this address I have confined myself mainly to the immediate situation and its difficulties as they relate to this country. It is this situation and these difficulties with which we are pre-eminently concerned at the moment, and we may reasonably hope that they will be coped with. But there will still remain much of the world-problem of which the present crisis is a manifestation. With this problem no nation can cope alone; it is an international problem. It is no exaggeration to say that, until it is so treated, the social, economic, and political future of a very large part of the world will continue in a state of precarious uncertainty.

The Chairman, in introducing Professor Daniels, said that a very suitable subject and lecturer had been selected to commence the Lancashire Section's winter session. He commented on the fact that we were living in extremely difficult times, and it seemed to him that at the present time we ought to consider all economic subjects on a National basis. He urged the appointment of a National Commission to investigate Fiscal Policy solely from an economic standpoint. He welcomed the opportunity of listening to Professor Daniels.

Subsequently Mr. Boothman said that Professor Daniels had given a very faithful, though perhaps ruthless, diagnosis of the situation. He called upon Mr. Frank Wright and Mr. W. W. L. Lishman to propose and second a vote of thanks, which was heartily accorded.

NOTES AND NOTICES

Examination in General Textile Technology

The next Institute Examination in General Textile Technology, in connection with applications for the Associateship, has been fixed to take place on the 9th December. The examination will be conducted at Headquarters, Manchester, and at certain other centres according to the number and location of candidates. For the first time, it is expected that arrangements will be effected for the conduct of the examination in overseas countries. Negotiations are proceeding in respect of candidates in India (Bombay), South America (Buenos Aires and Sao Paulo), and South Australia (Mount Gambier).

Institute Annual Competitions

The entries for the above-named Competitions, in reference to the design and structure of woven fabrics produced by students at Technical Colleges and Schools, are satisfactory, not only in number, but in the matter of better representation of districts. The specimens of competitors have already reached the Institute and the Competitions Committee are proceeding with the work of adjudication.

The prize distribution ceremony is fixed to take place on the afternoon of Saturday, 5th December, and the preceding day, Friday, 4th December, the exhibits will be displayed in the Geographical Hall above the Institute's Rooms at Manchester.

Library Facilities for Members

The development of the Library, by continuous accession of additional books and periodical textile literature, and by the extension of loan facilities, has resulted in a marked increase of demand in connection with this service. Increased use of the Library is indicated by greater demands for the loan of books either by means of personal call, messenger, or postal request. Copies of the catalogue are available and are sent post-free to members at a charge of sixpence each. The Members' Room at the Institute premises now houses the main portion of bound volumes available, and also current textile periodicals, the range of which is exceptionally wide. There is ample accommodation for writing and reading, and telephone extension is provided for the use of visiting members.

Lancashire Section Meetings

The second item in the current session of meetings of the Lancashire Section of the Institute, fixed to take place in the Geographical Hall, above the Institute Rooms at Manchester, on the evening of Friday, 13th November, promises to prove of exceptional interest. A paper is to be contributed on "Cotton Textiles for Electrical Installation," by Mr. R. I. Martin, A.M.I.E.E., of the Engineering Laboratory of the British Thomson-Houston Co. Ltd., Rugby. Specimens of the textile materials referred to will be displayed and there will be lantern illustrations. The subject has a definite bearing on the extended uses of cotton materials for industrial purposes. The paper will deal with the various uses of cotton yarns, tapes, and cloths for electrical insulation, various parts of electrical apparatus and machinery, whilst the important properties required and the principal methods of testing the materials will be indicated. The object of the paper is to give the textile industry a statement as to the purposes for which electrical engineers utilise cotton textiles, and to explain the particular requirements in regard to supplies.

Midlands Section

The Committee of the Midlands Section of the Institute, under the chairmanship of Mr. Thomas Morley (Leicester), has completed its work of arrangement of meetings for the current session, and already the printed programme has been issued to members in the Section area. The programme includes four meetings for lectures or discussion, and three visits to works. The first item was a paper on "Knitting Machine Developments," by Mr. John Chamberlain, F.T.I., Honorary Secretary of the Section, on the 21st October, at Nottingham. On the 11th November there will be a visit to the works of Messrs. Birkin & Co. Ltd., at New Basford, Nottingham, whilst on the 9th December there will be a meeting at Leicester jointly with the district branch of the Society of Dyers and Colourists, when Messrs. J. B. Lancashire and H. L. Long, B.Sc., A.I.C., will deal with the "Aims and Objects of Research in Knitting." Events are arranged for January, February, and March of next year—at Hinckley, Loughborough, and Leicester respectively—and announcements will appear later in this *Journal*.

REVIEWS

The Fall of Prices. By John A. Todd. Published by the Oxford University Press. (68 pp., 2s. 6d. nett.)

Principal Todd of the Liverpool School of Commerce has written what he describes as "a brief account of the facts, the probable causes and possible cures" for the fall in prices. It is now a quarter of a century since Professor Gustav Cassel formulated his "relative" gold analysis, ten years since it was adopted by Lehfeldt, and five since it was applied to the monetary gold supply by Mr. Kitchin; and yet, apart from a brief reference (p. 29), Mr. Todd makes no mention of a method which revolutionised the treatment of gold and prices. Instead, he reproduces, as in the earlier editions of his "Mechanism of Exchange," the figures of gold output and annual prices, not even on a ratio scale, and without a word as to the existence of diagrams which give a much better picture of these relations. But, ignoring the calculations of Dr. Cassel, Mr. Kitchin and Sir Henry Strakosch, and forgetting Mr. Keynes' distinction between the total stock of gold and the "free" supply, he accuses "those who put forward the theory that the fall in prices is due to too little money" of "not taking the trouble either to prove by statistics that the amount of money has been inadequate, nor to show by argument why that amount must necessarily be in strict proportion to the stock of gold" (p. 14). Accordingly he proceeds to supply what he suggests is the first "omission" by "an examination of the statistics," characterised by misinterpretation of figures in themselves irrelevant to the question. Similarly, in discussing the division of the Bank of England's gold between its two departments, he ignores the valid criticism of the Acts of 1844 and 1928.

Mr. Todd's revised examination of the deflationary post-war policy is less satisfactory than that which he published in 1926. He now declares that in April 1920 the Bank "was forced to raise its rate to 7% in order to stop the inflation," and that "immediately they had achieved their purpose, as witnessed by the upward movement of the Reserve, they began to reduce it" (p. 25). In fact, however, the previous rise to 6% had begun to take effect on prices in January 1920. But this criterion was ignored by the authorities, and a 7% rate imposed, which was maintained until April 1921, seven months after the Bank's own inferior criterion, its Reserve, had begun to respond. Moreover, deflation in 1920 was not "inevitable" as he suggests. The greatest opponent of inflation, Dr. Cassel, urged that prices should be stabilised at the higher level, and that the evil of inflation should not be added to by the disaster of deflation.

In his explanation of the crisis of 1929, Mr. Todd claims that the Bank began to reduce its rate "before the real fall in prices began" (p. 26). But the Board of Trade index which he uses is relatively insensitive, and the *Statist* and other indices began a continuous fall one or two months before Bank rate. He then offers the figures of the joint stock banks' advances and deposits (in themselves unsuitable for showing the circulation of industrial credit) as proof of the adequacy of credit facilities (p. 28), and actually ignores their trend. For it is not sufficient that advances should increase. In order that purchasing-power should be maintained, it is essential that the industrial circulation should increase proportionately to the potential volume of transactions. As it was, the total, after recovering from the collapse of 1929, is still much below the trend of 1926-28, which was far from rising abnormally. Finally he observes that bankers' clearings "rose steadily from 1921 to March 1930" (p. 29). On the contrary, they did not begin to rise until 1923, fell after the return to gold in 1925-26, and again in the last quarter of 1930. Moreover, the City clearings are even less relevant than are total advances, for they represent mainly financial transactions.

It may be said that these are mere details, pardonable in a topical pamphlet by a busy School of Commerce Principal, but several fundamental errors follow. Mr. Todd thinks that the statistics of stocks of staple commodities show that "increased supplies had a great deal to do with the fall in prices" (p. 40). Of course there is little doubt that if the supply of these commodities had not increased appreciably their prices might not have fallen, but the actual fall could only be attributed to increased supplies if these were in excess of the world's *real* requirements. In fact, increasing production is generally accompanied by rising prices; and Mr. Todd is confusing supply with stocks, which increased as a *result* of the slump. But he has original theories as to the proper behaviour of prices.

After admitting that many primary prices have been brought "well below the cost of production," he declares (p. 42) that the "slow" downward movement of prices from the post-war boom "should have continued," but was checked by the "fictitious" prosperity of America in 1928. Presumably he is referring to the decline after 1926, though why this should be regarded as proper would surely be as difficult to show as to maintain that American prosperity was any more "fictitious" than is the depression now ruling amid plenty.

Mr. Todd concedes (p. 46) that if it is true that the world's capacity to produce is being strangled by monetary difficulties, then the position is simply intolerable," and that "As long as there is the faintest chance of this charge being true it is necessary to consider what can be done." But his consideration does not afford much help. Instead of admitting, as even Dr. Cannan does now, that the monetary demand for gold is excessive or that minimum reserve ratios are absurd, he suggests that the banks' sterile hoards should be increased by "discouraging the use of gold in industry and the arts . . . by imposing a tax on such uses" (p. 49). That is to say, the world is to be deprived of gold for useful purposes in order to pander to the notions of prestige and security yet current with the central banks and certain of their customers. The last ten pages of the pamphlet are good, but do not, in the reviewer's opinion, compensate for the deficiencies indicated above. G.B.

A Glossary of Wool Terms. Published by Eavenson & Levering Co., Camden, New Jersey, U.S.A.

Realising that each generation needs enlightenment as to the meaning and proper application of many of the terms used in the textile trades, the compilers of this work have made a useful contribution to this end by combing diligently a number of reference books bearing on the raw material section of the wool industry, and as a result have produced a glossary of wool terms which if generally used will prevent much misunderstanding in the future. The book, excellent as it is in its definitions, only touches the fringe of the subject Every wool centre has coined for itself words which have little or no significance outside its own circles. This is particularly true in this connection, as many of the terms and definitions are of distinctly American origin and use. While many of the terms defined are in use in English wool areas, others are included which have long been obsolete in this country, particularly some which used to be employed for sortings of English wools. The book is handy in form, the definitions concise and clear, and may be recommended as of especial value to those desirous of becoming acquainted with the wool terms as generally used in America. J.D.

Deutscher Färberkalender 1931. Verlag Deutscher Färberkalender, Wittenberg. (Pp. 236. Price 5 marks.)

The current issue of this year book maintains the quality of previous years as far as the variety and wide scope of the subjects it deals with are concerned. In a book whose formal and general arrangement reveals its ambition to be in constant use as a pocket book, it is perhaps of rather doubtful wisdom to increase the weight unduly by articles of general and historical interest, such as those on the application and influence of rayon in the textile industry, fastness in general, and an illustrated history of silk dyeing in the eighteenth century, where the treatment gives one the impression that there is a rather too generous display of broad principles. The more summary and tabular the article, the more appropriate is its inclusion in a year book. To compensate for this, there are very interesting and topical treatments of spray printing, hand and mechanical; articles upon the control of the bleaching process and the testing of bleached goods. An article upon strength testing of materials is welcome, as drawing attention to this rather casually regarding subject, although the article itself contains nothing very revolutionary. A simplified scheme for the recognition of colours upon cotton fabrics is included. Of greatest interest to the dyer and dyeworks chemist is a tabular summary of new colours and auxiliary products introduced during the year, along with remarks on their application and properties. The list appears to be restricted to German and Swiss firms. There is also a short summary of patent literature, machinery innovations, and new books. The section which gives a brief digest of the syllabuses of German and other continental schools of dyeing contains much information not otherwise easy of access.

F.S.

Artificial Organic Pigments and their Applications. By. Dr. C. A. Curtis. Translated from the German by Dr. Ernest Fyleman. London: Sir Isaac Pitman and Sons Ltd. (pp. viii+291. Price 21s.).

The German edition of this book has already been reviewed in this *Journal* (Dec. 1930, Vol. XXI, No. 12, page P203), and most of the opinions expressed in the review apply to the English edition, which has been very adequately translated by Dr. Fyleman. In a special foreword to the English book, the author has made a graceful reference to the high standard of excellence of the work of English printers and the English varnish industry. The book is essentially a practical manual and perhaps, therefore, the plea in a former review for a rather more extended treatment of the theoretical considerations should not be stressed too much in this notice. Since chapters on lake preparation have been included in the earlier part of the book, it seems rather a pity that the newer views on chemical combination and the more extensive knowledge of the colloid chemistry of precipitation have not been marshalled as an aid to the closer understanding of a branch which presents so many practical difficulties. Signs of the times are indicated in the inclusion of references to the cellulose esters and substances of the artificial resin class as vehicles. The extensive tables summarising the properties of the pigment dyestuffs have been supplemented in this edition by others covering the products of firms actively operating in this country.
F.S.

Filature du Coton. Le Cardage. By Louis Studer. Published by L'Edition Textile, Paris, 1931 (198 pages, 130 illustrations. Price; 55 francs).

This book can be thoroughly recommended as giving a complete detailed description of the mechanism of the standard carding engines of British and French manufacture, including accessories like grinding and stripping devices. We welcome the departure from the usual custom of crowding the whole of spinning into one text book, believing that the time is ripe for a series of monographs dealing more exhaustively than hitherto with separate branches. The author does not attempt to discuss carding from the point of view of the cotton. His theory of the action of the card can be gauged by the repetition in his first paragraph of the old fallacy that carding parallelises the fibres. We would invite him to examine side by side card sliver and draw-frame sliver, and notice the difference.
C.W.

Chemische und Physikalische Technologie der Kunstseiden. By Wilhelm Weltzien. Published by Akademische V.m.b.H., Leipzig, 1930 (xix + 521 pp., 261 figures, and 8 plates).

This book is an achievement of some merit in so far as it deals with the whole subject of rayons from raw material to finished product in 500 pages.

It is divided into three sections, the first of which deals in two chapters (154 pp.) with the properties of natural fibres particularly those used as raw materials in rayon production—and the properties of artificial fibres. In both these chapters there is an orderly account of morphology, chemistry, physics, and colloid chemistry of the subject matter.

It is a pity that the results deduced from inaccurate calculation in Knecht and Platt's work should be included on page 17 in dealing with absorption of caustic soda by cellulose and that the author was not able to include the recent work of Neale, which clarifies the whole subject of swelling and absorption of alkalis by cellulose on the Donnan equilibrium. The section is therefore already out of date.

There is no mention of the extensive work done at the B.C.I.R.A. by Urquart on moisture absorption of cellulose materials. In discussing swelling the centrifuge method of Conrad and Spencer should have been mentioned. This is particularly useful as a commercial test of swelling.

Early in Section II a good account of the physics of viscosity is given, though probably the account would not satisfy the physicists. The simple viscosimeter depicted on p. 169 does give excellent absolute values, provided precautions are taken to standardise the instruments with, say, alcohol-water mixtures or concentrated sucrose solutions as recommended by the Washington Bureau of Standards.

These general considerations occupy 16 pages, followed by a detailed consideration of copper rayon, 20 pages; viscose, 44 pages; nitro rayon, 8 pages; acetate rayon, 13 pages; and other processes, 5 pages.

The largest part of the book is Section III (216 pages), which deals with the manufacturing side—twisting, reeling, winding, knitting, weaving, weaving faults, bleaching, bleaching faults, drying, and dyeing. This section is well done in the compass allotted to it. One page is even devoted to household washing and bleaching of rayons. The Mohr bleach and the Thiess (continuous hot acid steep) bleach processes receive adequate attention, these being apparently common in Germany. Progress in this direction would appear to depend now mainly on mechanical considerations.

The mercerisation process given on p. 480 for mixed goods, using a protective colloid for the rayon, is not the only one available.

The dyeing, printing, and finishing of rayons is fully dealt with and there is a very complete list of fastness tests.

In the perspiration tests given (pp. 403, 439) an alkaline treatment is followed by an acid treatment. In view of recent work on human perspiration would not the order be better reversed?

In spite of the general excellence of this work, which incorporates so much of modern methods, the reviewer is of the opinion that the last two sections could have been expanded and the first section cut out entirely.

Is there the need (apart from that of students) to deal with the physics and chemistry of rayon between the same covers as the technology of it? The technologist out to improve his products will want to wander over the whole field of physics and chemistry.

The book is well got up and delightful to handle, both of which desiderata one has become accustomed to expect from these publishers. It has a detailed table of contents and adequate indexes. It is not priced but is probably about 30 to 40 marks.

It should be made available to all workers on rayon. F.C.W.

Clothing: An Account of its Types and Manufacture. By F. S. Brereton, C.B.E. Published by B. T. Batsford Ltd., London, 1931 (84 pp. and index. 4s. net).

It is about a hundred years since the publication of Lardner's Cabinet Encyclopædia, which did so much for the education of the public in history, science, and manufacture, and in consequence of so great a lapse of time, much that it contained, especially concerning the two latter subjects has become obsolete. Although there has been a continuous output of technical works in recent years, there has been a dearth of such as treated their subjects in a really popular manner, and at the same time sufficiently technical to be worth the attention of those engaged in the pursuits described therein, but the "Essentials of Life" series seems destined to be of great value in this respect.

The volume under notice treating of clothing in its various aspects gives a rough outline of the history of the subject, from the skins and leaf clothing of primitive man and its development through the ages; not from the philosophical and metaphysical point of view of Carlyle in *Sartor resartus*, nor expatiating on Beau Brummel, Count D'Orsay, and the bucks of the last century, and with only a side glance at Savile Row and the modes of Paris, but, rightly considering that the mere history should be fairly well known to most readers of fair education and acquirements, the author has treated it briefly and concentrated his attention on the technique of the manufacture from the production of the raw material to the closing processes. The result is a series of descriptions of the various methods used which are not only interesting to the general reader, but, writing as one who has some technical knowledge of more than one of these, the present reviewer can recommend for the perusal of those engaged in the trades in question.

Flax is the first material dealt with as the most ancient fibre used in weaving (since it is probable that wool was first used in the form of felt) and its cultivation and the subsequent processes for preparing it for manufacture into cloth are clearly and succinctly described.

Cotton and wool follows, with a glance at the latter trade during the Middle Ages, when it was by far the most important manufacture in this country, and when the "Woolsack" was established in the House of Lords to keep Parliament in remembrance of its pre-eminence. The various mechanical appliances for

carding, spinning, and the weaver's loom are explained and illustrated, from the time of the prehistoric cave dwellers and people of the lake villages to the amazing development of these machines during the past 150 years. The illustrations are well chosen and remarkably well executed, those of former times from old engravings and aquatints, the modern machinery evidently from careful photographs.

The culture of the silkworm and the manufacture of this the premier textile industry forms the concluding chapter of this section, devoted to spinning and weaving.

The making up of textiles as apparel under mass production is fully described, with a history of the sewing machine which has rendered such possible. It is only 88 years since Hood wrote "The Song of the Shirt," and it was at about the same date that Macaulay prophesied that in 1930 "machines constructed on principles yet undiscovered would be in every house." The fulfilment of the prediction has rendered the poem now almost meaningless. The author attributes its invention to Hunt of New York, for of course the credit goes to the man who first placed the eye of the needle in the point (all else have been improvements only), but the usual authorities give the honour to Elias Howe, who patented his invention in 1846.

Gloves and the treatment of furs are fully dealt with and there is even a chapter on indiarubber in its relation to waterproofs.

An excellent account of modern boot manufacture is given, and is a revelation to those, and there are many such, who remember when it was a pure handicraft. It is now one of the most mechanised of trades. Felt hats and "the topper" follow and the central subject of the book (clothing) concludes with a chapter on dyeing and cleaning, but there is a subsection giving a short account of fastenings pins and buttons, and there is nothing that more forcibly brings home to us what a revolution has been made in the world by machinery. The old books on political economy used to hold up the making of pins and needles as examples of the division of labour when they were being made by hand, but if Adam Smith were to revisit the earth . . . In a volume treating so many and so diverse subjects it is perhaps inevitable that there should be a few slips—

P. 19—"Ten days from the time it (the silkworm) has been hatched it has grown from the minute thread it was to a worm some 3 inches in length." This is about the size of the mature larva and the time should be six to eight weeks.

P. 27—"Hardly two hundred years ago the spinning wheel was invented." It has been known in Europe from the fourteenth century and in a rude form was in use in the East from almost prehistoric times.

It may be suggested that in a future edition some account should be given of the hosiery manufacture, a not unimportant branch of clothing; such would round off and complete a book which combines in a marked degree the merit of readableness with much technical yet popular information. H.G.B.

The British Empire in 1950. A Peep into the Future. By George Moores, F.T.I., with an Introduction by Sir Gilbert Vyle. Published by John Heywood Ltd., Manchester (95 pages. Price 2s. 6d.).

A prosperous and united Empire, Great Britain flourishing and Lancashire with more spindles and looms running than ever before—this is Mr. Moores' encouraging vision of conditions in the year 1950. The ways in which our people overcame their difficulties are the subject of conversations which are supposed to take place in the new commodious premises of the Textile Institute which, in the year 1950, is to be the rendezvous of all concerned with the textile trades. Prior to the year 1932, unsheltered industries had been sacrificed by the Government to sheltered concerns. Attempts had been made to build up minor industries instead of strengthening and broadening the base of the vital export industries. There was a lack of able and willing representatives of the export industries in Parliament. Recovery from the long post-war depression was first stimulated by Parliamentary grants to the depressed trades in affording credit facilities for reconstruction purposes. A manufacturers' supply association, as a successful experiment in co-operative enterprise, had cut down the costs of supplies. Powerful vertical combinations had set a new pace in competitive efficiency both for individual firms and for the established price-ring organisations in complementary

trades and services. Industries had dealt separately with their own Health Insurance problem, at much lower cost, and thus remedied the scandal of State Insurance. An Imperial Parliament for industry and commerce had co-ordinated the industries and trades of the Empire. Apart from these essentially industrial activities a great voluntary effort on the part of the country was fast wiping out the National Debt; and Imperial army and navy services, with unrestricted movement of Britons about the Empire, had helped to better Empire relations and effective Empire settlement. These factors in the author's vision of recovery, if somewhat sketchily discussed, are unexceptionable from the point of view of consistency. The author's attack on the Daylight Saving Bill, which, prior to its supposed repeal, is held responsible for frivolous nights and consequent unfitness for work next morning, has hardly a consistent solution. Mr. Moores tells us that the country ceases to deceive itself, by changing the hour, and that businesses ran from 8 a.m. till 5 p.m. in the winter and from 7 a.m. till 4 p.m. in the summer; the summer evenings then, presumably, not being spent in games and other pleasures. Again, the final step in Mr. Moores' programme of consolidating the Empire consists in the adoption of Empire free trade, with tariffs against the rest of the world and no tariff restrictions within the Empire. Mr. Moores, nevertheless, in his earlier chapters makes a strong case against tariffs. Though very unequal in the soundness and practicableness of his measures in promoting the objects he has so sincerely at heart, his book is suffused throughout with the right spirit—a spirit of mastery in face of difficulties—and an undiminished confidence in the ultimate recovery of the cotton trade and of the Empire. As such, it provides a helpful antidote to the defeatism and "ca' canny" policy now preached by many responsible leaders of industries to the younger generation. E.E.C.

"Baumwolle Auf Zeit." By Dr. Theodor Buhler. Published by the Verlag der Hochschulbuchhandlung Krische & Co., Nurnberg, 1931. (122 pages. 1 80 R.M.)

This work on "the Principles of Future Trading in the Cotton Industry" appears as a second and enlarged edition of the pamphlet "Das Baumwollterming eschaft," which has, since its publication in 1928, been regarded as one of the most authoritative expositions of the subject from the German standpoint. In the cotton industry, the author points out, the time-lag between the supply and the consumption of the raw material necessitates the operation of a futures market, and he insists, somewhat over-emphatically perhaps, on a strict differentiation between legitimate speculation and gambling as such. The primary function of the future market is shown to be the damping, if admittedly not the perfect stabilisation, of variations in the price level and the consequent protection of the grower at one end and the manufacturer at the other. The essential distinction, however, between long and short period fluctuation is not clearly demonstrated. By the smooth equating of the market it is true that freakish fluctuations are counteracted, but, in the long run, future trading is powerless to affect the equilibrium between available supply and effective demand. The body of the work consists of three main divisions. Section A (45 pages) is a theoretical discussion of the scope and significance of future trading and on account of its development from the founding of the Liverpool Brokers' Association in 1841. Section B (42 pages) deals with the practice of the futures market and discusses the effectiveness of hedging as a form of trade insurance. A special sub-section is devoted to a descriptive account of the organisation and procedure of the Bremen Cotton Exchange. The rapid progress of future trading in Bremen since its inception in 1925 is described, and the opinion is ventured that it is only "a question of time" before Bremen, which is exclusively concerned with American cotton, takes over from Liverpool the control of the Central European business. In the Appendix, which constitutes Section C (13 pages), statistics of cultivation and spindleage are given, together with a bibliography, a list of technical terms used by the market, and reprints of New York and New Orleans contracts. A slip-pocket in the back cover contains samples of the various forms in use on the Bremen Exchange. The book is well printed, lucidly written, and attractively presented, and its glossary of English and German technical terms should prove particularly useful to those interested. A.T.P.

"Marktbeobachtung und Absatzorganisation in der deutschen Baumwollweberei." By Dr. rer. pol. Otto Bickel, Diplomkaufmann. Published by the Verlag der Hochschulbuchhandlung Krische & Co., Nurnberg, 1931. (197 pages. 10,50 R.M.)

With considerable skill the author has presented within the limits of a single volume an exhaustive description of the German cotton weaving industry in all its phases, as well as an account of the scope and importance of scientific analysis in the treatment of industrial problems of which that description is itself an illustration. Most of the earlier work on the economics of individual trades and of the cotton industry in particular, it is suggested, have been too preoccupied with the productive processes to pay due attention to the distribution and consumption of the finished goods. Yet market analysis, in the author's view, is as important a subject of study as costs, and he quotes with approval the assertion that "the problem facing the cotton weaving industry is not a problem of production but one of markets." Unless it refers to the technical side of production this is a doubtful thesis, for the two terms of the equation are interdependent. The rate of consumption cannot be considered apart from the rate of actual or potential supply, and a depression at a given time might be attributable to surplus productive capacity with as much justice as to underconsumption. The first part of the book deals with the structure of the weaving industry and with its place in the general economic framework of the world and of Germany in particular. Statistics published by the International Cotton Bulletin and the German Government's Statistical Year Book (1929) are used in a discussion of the relative importance of the industries of Great Britain, Germany, and the United States, but no reference to Japan is made in this part of the work. Scientific market investigation differs from common observation in that it is concerned with quantitative relationships, and Section II is devoted to a statistical analysis of the German market for cotton goods. For the purposes of the survey two main classes are somewhat arbitrarily distinguished: goods intended for personal wear and goods of general utility. These comprise the groups—men's wear, women's wear, and professional wear; and casement cloths, tablecovers and furnishing fabrics, all of which are further sub-divided. The problem of fashion is discussed at length and the interesting suggestion is made that a "fashion observation bureau" should be instituted to investigate fashion changes and ultimately even to produce them by discovering the psychological laws which they follow. Section III deals with methods of distribution and the rapid rise of co-operative trading in recent years. The relative merits of large and small scale enterprises are discussed, and the author concludes by referring to recent concentration in the Lancashire cotton industry. The book, in spite of its somewhat indirect style, should well repay study, both for its systematic treatment of every aspect of the cotton weaving industry and for the technique of market analysis which it elaborates. A.T.P.

PUBLICATIONS RECEIVED AND PLACED IN THE INSTITUTE LIBRARY

Year Books of the National Association of Cotton Manufacturers for 1930 and 1931. A comprehensive statistical and technical work of reference on the cotton trade. Published by the Association from its headquarters at Boston, Mass., U.S.A.

Proceedings of the World Engineering Congress, Tokyo, 1929. General Reports, and Volume XXVIII Textile Industry.

Knitting Trade Directory, 1931-32. Published by John Heywood Ltd., Manchester. 2s. net.

The third issue of a very handy directory. Gives a complete list of firms in the United Kingdom engaged in machine knitting.

Kingston's Price Equivalent Tables. Published by Kingston's Translations Institute, Leadenhall Street, London. Price 2s.

Gives prices per hundredweight and 100 kilos. from ½d. to 250s. per cwt. for various European countries.

Kingston's Continental Price Conversion Tables. Publisher as above. Price 4s. net.
Giving price equivalents at stabilised exchanges for imperial and metric weights and measures and vice versa.

The Australian Association of British Manufacturers. Twentieth annual report and list of members.

Revindicacion Catalana. Del invento del tisaje mecánico del terciopelo en doble pieza, como asi también de todos sus posteriores. Par Pablo Rodón y Amigó.

Canada: Department of Trade and Commerce. Publications issued by the Dominion Bureau of Statistics.
The Canada Year Book, 1931.
Prices and Indexes, 1913-1929.
Textile Industries of Canada, 1928.

Methods for Suppressing Dust in Asbestos Textile Factories. H.M.S.O., 1931. Price 1s. net.
A report on conferences between employers and inspectors dealing with this subject.

Skinner's Cotton Trade Directory of the World, 1931-1932. Published by Thomas Skinner & Co., Old Broad Street, London. (1,252 pages. 20s. net.)
The ninth issue of a standard work of reference. Has been much improved and keeps its place as an often-referred-to book.

The British Launderers' Year Book, 1931-1932. Published by the National Federation of Launderers, Lancaster Gate, London.
A very well-prepared and welcome addition to the shelf of directories and year books.

Syllabus of the Prussian Technical School for the Textile Industry. Forst (Lausitz.) Issued with a pocket book for those in attendance at this school.

Illustrated Catalogue of Cotton Spinning Machinery. Issued by John Hetherington & Sons, Manchester.
Contains also machinery calculations, speeds, and productions.

Macinlop Anti-corrosion Rubber. A publication by Macinlop Ltd. Deals with the properties and uses of rubber as an anti-corrosion material.

Cambridge Thermo-Electric Pyrometers. A booklet issued by the Cambridge Instrument Company, Grosvenor Place, London.
Deals with the measurement and recording of temperatures up to 1,400° C. (2,552° F.).

GENERAL ITEM

Adult Education in Art

An interesting scheme in relation to Adult Education in Art has been announced by the Manchester Education Committee. The object of the scheme is to provide facilities at the Municipal School of Art to enable members of the public beyond the age of ordinary students to meet together for discussion, informal lectures, and experimental practice in various branches of art. Approved groups of adult students may be given accommodation on Wednesday evenings during the Winter session and it is anticipated that meetings will take the form of lectures and demonstrations open to the general public, as well as to members of the various groups. Particulars of the scheme may be obtained on application to the Principal of the School of Art, Mr. R. A. Dawson, A.R.C.A., F.S.A.M.

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PROCEEDINGS

Lancashire Section

Meeting at the Geographical Hall, Manchester, Friday, 13th November 1931,
Mr. William Howarth, Past-President, in the chair.

COTTON TEXTILES FOR ELECTRICAL INSULATION

By R. I. Martin, A.M.I.E.E.
(Engineering Laboratory, B.T.H. Co. Ltd., Rugby)

INTRODUCTION

Since the earliest days of electrical engineering, cotton, in one form or another, has been largely used for insulation purposes. A hundred years ago Michael Faraday wound up coils of wire which he insulated with twine and calico. Cotton tapes were also used by him and other early experimenters, particularly for insulating windings such as magnet coils. They found then, as we still do now, that cotton products were readily available, strong, flexible, and most adaptable to various shapes and forms, and these outstanding features have naturally been taken advantage of for numerous difficult and intricate coverings and protections of electrical conductors and windings. From those early days the growth of the electrical industry has been very much dependent upon the successful use of cotton textiles, and they have naturally entered more and more into the construction of motors, transformers, cables, and other apparatus.

Electrical engineers have generally had to adopt, for insulating work, materials primarily produced for other purposes by various industries; this has been particularly the case with textiles, papers, ceramics—such as porcelain—varnishes, and oils. In many cases, especially in the early days, engineers had to adapt to their uses products such as tapes and fabrics, papers and pressboards, manufactured without any regard for their ultimate use in electrical apparatus, and, consequently, considerable risks were often taken or the best possible use was not made of the materials available. The increasing demands of the electrical industry have, however, gradually enabled and, to some extent, induced other manufacturing industries to consider carefully these requirements, and, as time went on, to produce materials specially suited for the severe conditions to be met. Progress is naturally very dependent upon the industry, which manufactures the materials, understanding fully the particular uses to which its products will be put by the electrical engineer, and the technical requirements involved. At the same time, it is necessary for the user to study the conditions under which his materials are manufactured so that he can have confidence in them and utilise them to the best advantage.

This paper is intended to provide those in the textile industry with a general idea of the extent to which cotton products are used as electrical insulating materials, details of the main purposes for which they are required, and information concerning the technical aspect of the properties and other features affecting the successful employment of cotton goods for such purposes.

GENERAL CONSIDERATIONS

Owing chiefly to the pronounced hygroscopic nature of cotton it cannot normally be used for insulation purposes where high electric stresses are likely to be imposed on it, especially where the apparatus has to work under damp atmospheric conditions. It will be seen, therefore, that cotton insulations invariably have to be protected from moisture absorption by varnishes, rubber, bitumen, etc., and as a general rule they are not used as the primary dielectric, but function mainly as mechanical support and protection to other materials of better electrical properties. For example, the only important instances of the use of cotton for its insulating properties are as coverings for wires and conductors wound into coils, and also as coverings for cables, but in a large number of cases the cotton is only applied over another insulation, e.g. enamel or rubber, to act as a mechanical protective medium for these. Further, most of the cotton tapes, sleevings, and fabrics employed are for binding conductors and insulations together, and for providing strong protective coverings for coils, bars, windings, and various parts already insulated with such materials as micanite (made from overlapping thin flakes of mica bonded together with shellac or other special varnishes).

Another very important fact governing the successful use of cotton products in electrical machinery and apparatus, is that in practically all cases a good deal of heat is developed in the windings and other parts, causing the normal operating temperature to be considerable, e.g. 80 to 100° C. The ability of the insulations—especially those of organic nature—to withstand continued exposure to such temperatures has, therefore, to be considered very carefully, as the life of the whole machine is mainly dependent upon the deterioration of the insulations. It will be seen later that this very largely determines the size, cost, and capacity of the apparatus, as it has to be designed so that the temperature will not exceed a safe limit for materials used in its construction, and it is generally organic fibrous components such as textiles, papers, and pressboard, which are most susceptible to the effects of heat. This point must be stressed as it is often overlooked when considering the suitability of cotton and other organic products for use in electrical apparatus. In some cases the whole of the windings are continuously immersed in mineral insulating oil—for example, most transformers, especially those for high voltages—and in certain instances the apparatus has to work in fume-laden atmosphere. It will thus be realised that the service conditions for which cotton textiles are required by the electrical engineer are severe, and it will be found that the conditions under which they are applied and handled during the manufacture of electrical apparatus are, on the whole, no less onerous, calling for the utmost uniformity, mechanical strength, chemical stability, and excellence in other respects.

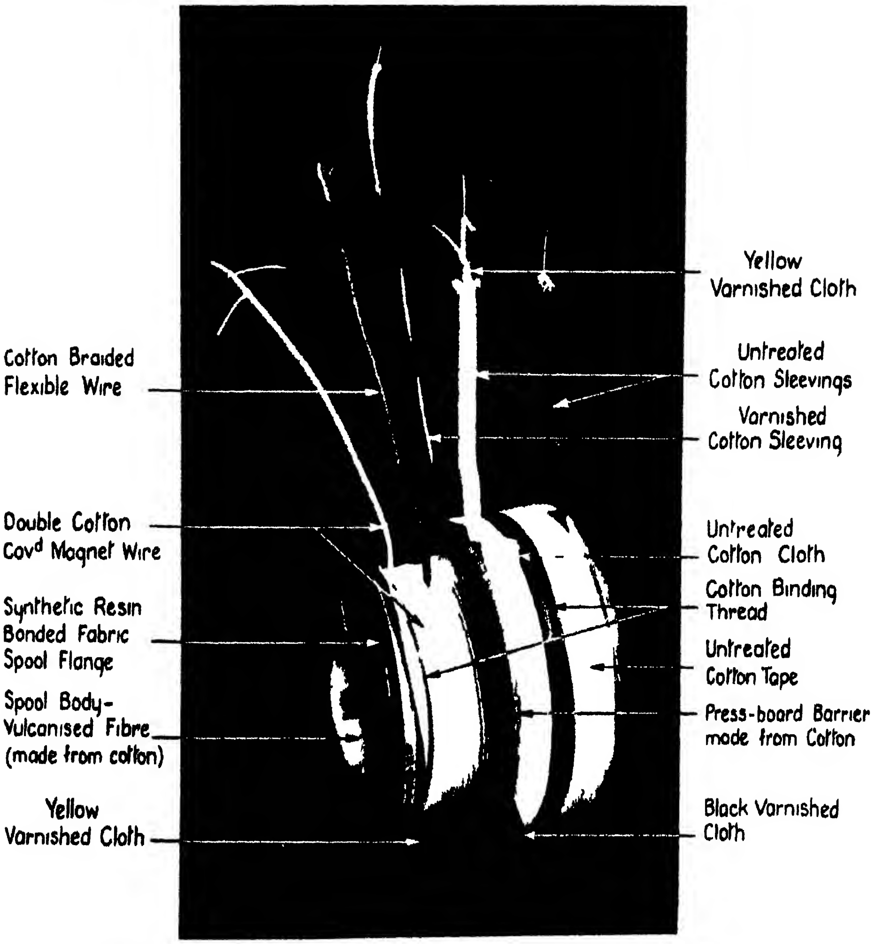
TYPICAL EXAMPLES OF THE EMPLOYMENT OF COTTON TEXTILES IN INSULATION

A brief résumé of the principal uses of cotton textiles for insulating purposes will now be given, together with indications of the important properties required in each case, so that before considering the technical aspects in more detail, those not generally familiar with the actual applications of cotton textiles to this work can appreciate the general requirements. It is not intended, however, to give a complete summary of these applications, as full details can be found elsewhere.[1,2,3] The uses of cotton goods as electrical insulators can be divided as follows—

(1) Primary insulation, e.g. coverings on wires.

(2) Mechanical support and protection to other insulations.

(3) The basis of manufactured insulations, e.g. varnished cloths and sleevings, and bonded laminated boards, etc.



(B.I.C.C. Ltd.)

Partly wound Coil illustrating typical use of Cotton Textiles for Electrical Insulation

Yarns and Threads

(a) Primary Insulation on Wires (lapped)

Yarns are applied to copper wires, both round and rectangular, by lapping—one, two or three layers being served, usually in opposite directions. The most commonly used covering is two laps of cotton, the wires being known as "Double Cotton Covered Wires" (D.C.C.). The laps being applied in opposite directions help considerably to prevent unravelling of the coverings when the wire is cut. These conductors, often known as "magnet wires," are used very extensively in the windings of coils for armatures, fields and stators of motors and generators, and for transformer windings, operating coils of control and switchgear, and all manner of electro-magnetic windings where long lengths of uniformly insulated wires are required. In these cases the insulating properties of the yarn *are* important, as often the cotton is the only dielectric between parts of the winding at different potentials. There are, however, cases in which the cotton is applied over an enamelled wire, the enamel acting as the main dielectric, and the cotton partly as a dielectric but chiefly as a mechanical protective layer to the enamel. In this manner it acts efficiently as a buffer between adjacent wires, preventing the enamel coverings from rubbing each other with possible damage to one or both during winding operations or in service. The presence of the cotton (usually a single covering) as a second line of defence, is particularly helpful in coils for alternating current work, where breakdown between turns is, for electrical reasons, especially dangerous. The space taken up by cotton coverings on wires is of great importance in most windings, particularly on wires of small diameter, but wires can be obtained with various thicknesses of coverings, as indicated in Table I. In some cases additional coverings are applied by braiding, especially

Table I

Details of Typical Cotton Covered Wires (Lapped)

Type of Covering		Total Thickness of Covering (mils.) (extra on diameter): Bare Diameter of Wire ·0076 in.	·036 in.	·128 in.	Yarns Used: Bare Diameter of Wire ·0076 in. Count	Ends	·036 in. Count	Ends	·128 in. Count	Ends
Single Cotton (S.C.C.) ..	Specially fine .	3/3·5	4/5	6/7	160s	5	80s	18	80s	24
,, ,,	Ordinary	4	5/6	7/8	120s	5	60s	16	60s	24
Double Cotton (D.C.C.)	Specially fine ..	5/6	6/7	9/10	140s	{5, 5}	120s	{19, 19}	80s	{22, 22}
,, ,,	Ordinary	7/9	9/11	12/14	120s	{5, 5}	60s	{13, 14}	60s	{20, 20}
Triple Cotton	Specially fine ...	-	16	16	–	---	{120s, 80s, 80s}	18, 15, 18	80s, 80s, 80s	21, 22, 22
,, ,,	Ordinary	--	20	20	—	—	60s	{13, 14, 16}	60s	{19, 20, 20}
Enamelled and S.C.C. ...	Specially fine ..	4·2	7·5	9/10	140s	5	80s	18	80s	24
,, ,,	Ordinary	5	9/10	10/11	120s	5	60s	16	60s	24
Enamelled and D.C.C. ...	Specially fine ...	7	10	13/14	140s	{5, 5}	120s	{19, 19}	80s	{22, 22}
,, ,,	Ordinary	9	13/14	15/16	120s	{5, 5}	60s	{13, 14}	60s	{20, 20}
(Enamelled) ...		0·7	2·5	4·0	--	--	—	—	—	—

where large conductors have to be severely handled and bent during winding operations. Coils wound with cotton-covered wires are invariably treated, after thorough drying, with a good insulating and moisture-proofing varnish, or with a hot molten compound of bitumen, resins, etc. The outstanding properties required of cotton coverings of wires are thus—good length of staple; freedom from electrolytes and other injurious chemicals; resistance to deterioration by heat; good space factor; resistance to abrasion, and good electrical properties.

(b) Protective Coverings on Wires and Cables

There are many varieties of wires and cables in which cotton is used, in some form or another, more as a protective layer or covering than as the primary dielectric. The principal case is the braided cotton coverings of "flexible" wires, with which everyone is familiar; the most common example being the ordinary twin lighting "flex." In these instances the braided covering is usually a mechanical protection to rubber-covered stranded wire. It is obvious that resistance to wear by abrasion or "chafing" is all important in these cases; electrical and chemical considerations being of less significance. This is, incidentally, about the only use of cotton insulation where the colour is of any importance, different colours being used to give pleasing and distinguishing finishes to wires. The yarn for these coverings is usually glazed. There are many other cases where cotton is used in some portion of wires and cables, especially those for telephone work. In some cases untreated or specially treated strips of fine woven cotton cloth are included, e.g. to keep rubber from contact with the copper conductor in order to protect it from the action of sulphur in the rubber.

(c) Miscellaneous Uses of Yarns, Threads, etc., for Binding and other purposes

Various cotton yarns and threads are used for sewing, tying, and binding other insulations together, especially for holding the leads of coils. One important case is for binding over paper-wrapped conductors of transformer windings where the main dielectric is paper (untreated or specially prepared) and cotton yarn is lapped on the outside in the *opposite* direction to the paper, to hold the latter in place. In these applications of yarns and threads good tensile strength, chemical purity, and resistance to ageing are the chief attributes desired.

Another important application of yarns is in the special method of insulating coils on the Leesona machines, in which yarns are wound in with the wire, to form an insulating layer between layers of wires. Cotton yarns are also used to some extent in the weaving ot certain asbestos tapes (listings) and cloths, in order to give the asebstos threads more strength during and after weaving. Sometimes the quantity of cotton present in such asbestos woven fabrics is as high as 15% of the total. Cotton is also employed in some cases in the manufacture of asbestos papers for the electrical industry. Both the papers and fabrics are used chiefly where considerable resistance to high temperatures is required, the important characteristics not being appreciably affected by the presence of the cotton, which, as mentioned, is mainly required to give the necessary strength during manufacture and application.

Cotton Tubular Sleevings

Tubular woven sleevings, generally plain braided but sometimes knitted, are used in two ways—

(*a*) The untreated sleevings in short lengths are slipped over leads of coils, e.g. armature and stator coils of motors, and various other connections, to give additional insulation and protection where wires have to be bent and connections have to be made. The sleevings are thus generally treated with the other parts of the coils, etc., during varnishing and impregnating processes at a later stage. Various coloured sleevings are sometimes used to identify particular leads.

(*b*) The untreated sleevings may form the basis of special varnished tubing sleevings having good electrical properties and not requiring subsequent treatment. These are usually manufactured in short lengths, e.g. 3 or 4 feet, as they are required to be kept in a circular form after the varnish coating is baked on. Some varieties are particularly flexible, and these are used extensively for insulating connections of motor coils, transformers, leads of control gear operating coils, wiring on switchboards, and all manner of connections such as those in radio apparatus.

Details of typical sleevings, both untreated and varnished, are given in Table II.

Table II

Typical Cotton Sleevings used for Covering Connections

Approx. Diameter	Ends of Spindle	No. of Spindles
1–0·5 mm.	2	16
$\frac{1}{8}$ in.	2	20
$\frac{3}{16}$ in.	2	24
$\frac{1}{4}$ in.	2	32
$\frac{5}{16}$ in.	2	40
$\frac{3}{8}$ in.	2	52

NOTE—The above apply to soft cotton yarns, usually two-fold.
Glacé cotton sleevings of single yarns are also used, some being coloured

COTTON TAPES (UNTREATED)

A walk round an electrical winding shop gives the impression that selvedge cotton tapes, of widths varying from $\frac{1}{4}$ in. to 2 in., are amongst the most widely used materials. This is because they are invariably employed for the outer coverings of insulated windings, especially the coils of armatures, fields, alternating current motor and generator stators, and in numerous other important instances, particularly where parts have to be bound tightly together, e.g. leads and coils of high speed rotating windings. American, Indian, and Egyptian cotton tapes are used; the latter mainly for tapes where thinness combined with strength are required. In many cases, however, the space taken up by the tape is of importance, as it contributes very little to the actual electrical insulation provided on a conductor, but is necessary for mechanical protection and binding purposes. The utmost regularity of weave and thickness is, therefore, desired, this generally being assisted by gassing and calendering. Details of typical cotton tapes and webbings now in use in the electrical industry are given in Table III, from which it will be seen that these range in thickness from ·003 in. to ·028 in. and include both plain and twill (herringbone) weaves. Some tapes have a coloured warp thread in the middle to facilitate lapped tapings.

Table III

Construction and Properties of Typical Cotton Insulating Tapes and Webbings

Common Name	Type of Cotton	Thickness approx in	Threads: No of Ends in 1 in. wide tape	Threads: Picks per inch	Counts of Yarn: Ends	Counts of Yarn: Picks	Yards per lb.	Tensile Strength (lb.) 1 in. tape
1—Superfine	Egyptian or Sea Island	·003 to ·005	120 to 90	72 to 60	2/100 to 2/96	79 to 60	410 to 330	30 to 40
2—Fine ...	Egyptian ...	6·5	79	44	2/62	34	200	40 to 45
3—Ordinary or Dynamo	American or Indian ...	9·5	63	34	2/28	28 to 24	140	55 to 60
4—Webbing	American ..	·019	85	34	2/27	12	90	90
5—Webbing	American ...	·028	60	39	3/16	16	59	140

NOTE—Tapes 1, 2, and 3 are usually plain weave, gassed, and calendered.
Webbings 4 and 5 are usually herringbone twill weave, two repeats (uncalendered).

Tensile strength is generally of importance as, during taping operations, the tension applied is often considerable, especially when binding down armature conductors and covering transformer windings. Also the tapes are frequently used where mechanical stresses are expected during service conditions, e.g. due to centrifugal force on rotating parts, and magnetic repulsion of conductors during heavy overloads; in the latter case the forces can be very considerable on large generators and transformers. The webbings of "herringbone" weave are particularly useful where great strength and adaptability to curved surfaces are required.

Other mechanical properties, such as resistance to wear, and abrasion or disintegration from hammer blows, are important, but the predominant feature in this, as in most uses of cotton products in electrical windings, is the ability to withstand heat without marked deterioration of the strength. For this reason, therefore, as well as for others, it is important that cotton tapes should be as free as possible from any injurious chemicals which will tender the cotton when heated. The presence of these substances, e.g. organic acids, chlorides and sulphates, are also sources of possible danger to other materials likely to be in contact with the cotton products, and in the case of very fine wire coils they may initiate or cause sufficient corrosion of the copper to effect complete severance of the wire and failure of the coil. It is, therefore, necessary for cotton tapes, fabrics, etc., to be scoured or specially washed to remove these undesirable substances.

As it is often necessary to apply a smooth protecting varnish coating to the insulated parts after taping with cotton tapes, these should be uniform in structure and free from excessive nap. It is, of course, usual to singe the taped surfaces with a gas flame before varnishing, to ensure as smooth a surface as possible, and provide a uniform varnish film, which will thereby have the best resistance to moisture, oil, fumes, deposition of dust, and other external influences.

COTTON FABRICS (UNTREATED)

Cotton cloths are used in the untreated condition for a large variety of purposes where the flexibility and strength peculiar to woven cotton goods can be utilised, but here again they are employed more for mechanical backing and protection of other sheet materials than as insulations themselves. They are invariably unbleached as the colour is of no object and the maximum strength is required.

(a) Cotton Cloths used alone

Cotton fabrics from 2 ozs. up to 12 ozs. per yard are employed by themselves for a few purposes; the thinner cloths for interlayer insulation and coverings of small spools, and the heavier cloths for the protection caps of armatures and field coils, especially those of traction motors. In the latter cases closeness of weave and strength are particularly important to prevent ingress of dust, and damage of the coils during handling. Where the finer fabrics are likely to be used in contact with fine copper wires, it is necessary to have chemical purity to avoid corrosion and other troubles from electrolytes. Cloths of twill weave, such as drills, are especially useful where considerable strength is required, combined with adaptability for covering armature heads and field coils.

(b) Cotton Cloths as Supports for other Materials

Fine Egyptian cotton cloths are often used for backing such sheet insulations as flexible micanite, where the micanite, being delicate to handle, requires reinforcement to enable ready application to slot portions of coils, and, when slit into strips, for taping end portions. The cloth is sometimes varnish-treated, and is generally pasted to the micanite sheet with a suitable adhesive. Uniformity of weave and thickness, together with good resistance to tearing, are the chief requirements of these fabrics. In some cases the ageing of the cotton fabric due to heat is not of prime importance, as it is mainly required for supporting the micanite during *application*, and is not relied upon for service conditions when the temperatures may be excessive for cotton, e.g. 120–130° C.

Cotton Fabrics (Treated)

Quite a large variety of cotton cloths are "pretreated" with insulating and moisture-protective varnishes and compounds *before* they are applied to electrical windings, this group of treated fabrics being similar to those already referred to, e.g. 3½ oz. cloths to 12 oz. ducks. These are, however, quite distinct from the group generally known as "varnished cloths," which are described later. The former are merely treated to give them greater resistance to moisture, heat and oil, very little reliance being put upon their ultimate electrical properties, whereas, in the latter case, the materials are specially produced to give good electric strength. The "pretreated" fabrics are particularly useful for wrapping and protecting parts of windings which are difficult to dry and treat later with varnishes and compounds after completion. Details of these and other cotton cloths used in electrical apparatus are tabulated in Table IV.

Table IV

Details and Properties of Typical Cotton Cloths used for Insulation Purposes

Description	Thickness (in.)	Threads per inch: Warp (Ends)	Threads per inch: Weft (Picks)	Tensile Strength lb per inch width: Warp	Tensile Strength lb per inch width: Weft	Principal Uses
1½ oz cloth	·0035	112	150	19·5	20	Backing for micanite.
Insulation cloth* ...	·005	63	65	31	22	For varnished cloths (e.g. Empire cloth).
Seamless bias cloth*	·005	70	70	27	21	For seamless bias varnished cloth tapes
2 oz cloth	·008	75	58	17·5	10	Interlayer insulation, etc., in coils
3½ oz cloth	·012	70	66	32	30	Slot liner backings and syn.-resin bonded boards and mouldings.
Drill	·017	66	66	48	58	Protection caps and coverings of armatures, field and other coils
8 oz duck	·027	48	38	57·5	49	Treated with varnish for reinforcing other sheet insulations.
12 oz duck	·040	42	34	96	92	Synthetic resin bonded boards, mouldings, etc.

Note.—All fabrics are generally unbleached and of plain weave except cotton drill, which is "twill" weave.

* Weight per square yard is approximately 3 oz. These cloths are dressed and heavily calendered. All others are uncalendered.

Adhesive and other Treated Tapes

Very extensive use is made of adhesive and other forms of treated tapes, generally slit from cotton cloth treated with rubber, bitumen or other materials. The adhesive tapes are particularly useful for all manner of cases where connections, ends of cables and exposed terminals, etc., are required to be covered. The uses of these tapes range from motor car wiring and domestic installations, to traction motors and even larger machines in the industrial field, and practically everyone is familiar with these very useful and adaptable insulations. A certain amount of strength is necessary in the fabric for these tapes, but in this case the tearing strength is not required to be too high as they should be capable of being torn across fairly readily. The adhesive and electrical properties are, of course, determined by the type of treatment and covering material applied.

Varnished Cotton Cloth Products

We now come to what is, perhaps, the most important use of cotton fabrics for insulating materials. In the early days of electrical engineering the ordinary cloths on the market, such as calicos and cambrics, were utilised as already mentioned, but attempts were made to improve their electrical and moisture resisting properties by varnishing. Cotton tapes were also applied to conductors and then varnished several times to provide a good insulating coating. Difficulties naturally arose from the unsuitability of the cloths and tapes for this purpose, mainly due to the nap and the general irregularity of the surfaces of the fabrics allowing the varnishes to soak in; the formation of good varnish films was practically impossible and the electrical properties were very poor.

The next obvious step was to treat cloth which had been specially prepared to take a good varnish film, and, after thus making a good dielectric, to apply it as desired in the form of sheets, strips or tapes. Thus there originated the special varnished cloth products known to the trade as "Empire Cloths" (the original trade name of the Micanite and Insulators Co. Ltd. products), "Varnished Cambrics," and other names. Great progress has been made with these materials, especially since the war, and there are now many specialist firms making these and similar products in this country, in America, and on the Continent.

The cloths are varnished by passing through a bath of insulating varnish at a uniform slow speed, and then through a heated oven in which the varnish films are oxidised and hardened, several coats of varnish being thus applied generally in one continuous operation, the completed material being rolled up again on a batch. The varnishing machines are usually constructed with a vertical heating oven or "tower," the cloth travelling up between steam pipes, over rollers at the top, and down again close to the steam radiators, the temperature of the oven being between 100 and 120° C. This is necessary to secure the correct baking of the varnish film on which the electrical properties of the finished material so largely depend. Selvedge cloths, about 36 inches wide and 3 to 5 mils. thick, are in regular use for making sheet varnished cloths, and these are often cut into strips or "tapes,"* either parallel to the selvedges or at an angle, e.g. 45°, so that the threads are oblique to the edges ("bias cut tapes"). This latter condition has been found to be extremely useful, and in fact essential, for a large number of taping operations where strips cut parallel to the threads tear too readily and are not sufficiently adaptable.

The necessity for these bias-cut tapes in long lengths on reels caused the development of a special method of manufacture in which the selvedge cloth, when completely "finished," is cut obliquely, e.g. at 45° about every 50 inches, the pieces turned through 45° and sewn together, selvedge to selvedge. This gives a continuous length, with threads running at 45° to the edges, which is then varnished as in the case of a straight fabric, afterwards being cut into narrow tapes. The presence of the sewn joints is a disadvantage in many applications of these tapes, as the material is much thicker at the joints, and as a rule these are electrically weak places. Recent developments have evolved *seamless* bias tapes which are more economical. These are made from a tubular woven fabric (pillow casing) cut helically at 45° to the threads and then gassed, finished and calendered in the bias form. It is, therefore, delivered to the varnisher as a bias cloth, say 34 inches wide, and is varnished as in the case of selvedge cloths, the varnished material being slit into "seamless" bias tapes which are continuous for considerable lengths. The development of these seamless fabrics has been a very difficult matter, due to the very special finish and properties required, but although these were originally only obtainable in America, they are now being regularly produced in England.

* Note—In these cases "tapes" is a misnomer as there is no selvedge, but the term is in general use for narrow strips.

There are many interesting and difficult problems involved in the manufacture of these special varnished cloth products, especially as regards the finishing of the fabric, the varnishes used, and the varnishing process, but these cannot be dealt with in detail here. They have, however, been discussed elsewhere [1,3], and a British Standard Specification (BSS. 419–1931) now covers the properties of the sheets, strips, and tapes. It might be mentioned, however, that special attention has to be paid to the bleaching, scouring, or other cleaning process of the cloth, in order to preserve maximum mechanical strength and ensure chemical purity, so that subsequent heating during varnishing and use in service will not "tender" the cotton unduly. There are two main "schools of thought" regarding the best methods of finishing these fabrics: one holding that as little dressing as possible should be used so as to enable the varnish to impregnate the cotton thoroughly; the other maintaining that the cotton fibre should be protected, by starch or other dressing, from contact with the varnish which may tender the fibre by oxidation, and that the cloth should be finished so as to allow very smooth and uniform varnish films to be applied. In all cases, however, it is agreed that the nap should be removed as completely as possible, otherwise it may protrude through the varnish and give poor electric strength. The "impregnated" cloths are chiefly made in America, but the British practice is very generally to use well-dressed and finished cloths, giving good smooth varnish films of high dielectric properties.

The construction and properties of typical varnished cloth products are given in Table V. (N.B.—The electrical and chemical properties are, of course, mainly dependent upon the varnishes used.) The cloths are used extensively in sheet form as slot insulation in motor and generator windings, as spool insulation on field coils, and on the cores of transformers. The uses of the sheet, strip, and bias-cut tape-varnished cloth products are legion, the latter materials being particularly serviceable as a ready means of applying a good dielectric to all manner of awkwardly shaped conductors and parts, especially for connections of transformers, switchgear, and machines.

Bonded Cloth Laminated Products

A few cloths and tapes are used in the electrical industry as the basis of solid rigid insulation boards, wrappings, mouldings, etc., in which they form laminations bonded together with a medium such as a synthetic resin. These resins, particularly those of the phenol-formaldehyde type, have good bonding properties, and, although fusible at first, they can be hardened under heat and pressure to give products able to withstand temperatures such as 130 to 170° C. without appreciable softening. They are, however, somewhat brittle, and need reinforcement to give products of reasonable strength; here again the good mechanical and other features of cotton can be used to advantage.

Cloths are treated first by passing through a bath of "resin" dissolved in methylated spirits, and the coating dried in a tower varnishing machine as in the case of manufacturing varnished cloths. The resin-coated cloth is then cut up into sheets or pieces, and a suitable number of sheets stacked together between hot plates, or shaped pieces are inserted into a hot mould. In some cases adjacent sheets or pieces are placed with the warp threads displaced by 90° so as to equalise differences between the strengths in the warp and weft directions. The material is then pressed between heated platens of a hydraulic press, being held at a temperature of about 150° C. for anything from a few minutes to an hour or so, with pressures of 400 to 1,000 lb. per square inch applied. Owing to the fusion of the resin during the first stage of this pressing, the layers of fabric are well bonded together, and the material will conform to the shape of simple moulds, the resin being forced into all available air spaces between the threads of the fabric, and between pieces.

Boards of these bonded cloth materials are used as panels and terminal boards, and various mouldings, such as slot wedges and spools, are made from these

compounds, in most cases the cloth filling being preferred to papers, asbestos, wood-pulp, and other materials, because of the mechanical strength provided by the cotton fabric. Similar laminated materials are made from absorbent cotton rag papers, as the resin penetrates well into the paper and the *final* compound does not, therefore, absorb moisture readily. One disadvantage of the bonded cloth products is their rather high moisture absorption, which militates against their extensive use in very damp situations and for high voltages, but they are, nevertheless, in general use for a large range of purposes, the parts usually being well protected by varnishing. Incidentally, similar products such as Fabroil are used to a great extent as gear wheels and pinions where reduction of noise is important, e.g. in automobiles.

Properties of typical synthetic-resin bonded cotton cloth and paper boards are shown in Table VI.

USES OF COTTON IN NON-TEXTILE FORMS

Mention should be made of important uses of cotton for the manufacture of electrical insulating materials, such as papers, pressboard and vulcanised fibre, as, although the cotton is not used *finally* in the form of a textile, it is generally obtained initially as rags or fabric cuttings. The fundamental properties of cotton are taken advantage of in making these materials and they are extensively used. The cotton papers are particularly suitable where very absorbent papers are required to be bonded with synthetic resin to form solid boards and mouldings. Vulcanised fibre, at one time more in favour than at present, is made from cotton rag papers converted by treatment with zinc chloride, and has uses for low voltage insulation purposes. Of recent years excellent pressboards (similar to fullerboard) have been manufactured from cotton with or without other fibrous materials. In the last mentioned products especially, the pre-eminent characteristics of cotton are utilised to good advantage, i.e. mechanical strength, flexibility, absorbency, and good ageing properties, and the materials as now manufactured are especially good as regards electric strength, low dielectric losses, and freedom from conducting particles.

INSULATING TREATMENTS OF COTTON PRODUCTS

In addition to the rigorous conditions of manufacture and application of cotton textiles for insulation purposes already referred to, most of the materials have to be subjected to treatment processes involving drying, varnish or compound impregnation, baking, etc., which impose further hardships on them; the treatments are, however, mainly necessitated by the hygroscopic nature of cotton, which demands special protection against moisture. These treatments are also for the purpose of improving mechanical bonding, thermal conductivity, electrical performance, resistance to chemical fumes, oil, dust, and other external agents. Heat treatments, employing circulated hot air or vacuum, are used for drying, usually at temperatures up to 105° C. and sometimes higher. Impregnation with oils, waxes, varnishes, bitumen and other compounds are in general use, such treatments often being carried out at pressures up to 100 or 150 lb. per sq. inch.

PROPERTIES AND TESTING OF COTTON TEXTILE INSULATIONS

It will be seen, from the foregoing, that cotton products for use in electrical apparatus are required to undergo severe conditions of heat, and other agencies, both in manufacture, application, and final service, thus it is imperative that in making, selecting, and using these goods, all concerned should give special attention to the particular requirements of electrical work.

Considerable research work has been done in recent years on cotton textiles, which has been of great assistance to the electrical industry. The British Cotton Industry Research Association, the Research Department of the Bleachers' Association, and the British Electrical and Allied Industries Research Association (E.R.A.) have worked on the various problems involved in the use of cotton

products for electrical purposes, in collaboration with British manufacturers of yarns, tapes and cloths, and various electrical engineering concerns. Work has been done in the Engineering Laboratory of the B. T. H. Company on a number of these problems, especially in connection with varnished cloths. The Electrical Research Association, particularly, has encouraged and co-ordinated such work, and has developed recommended standard methods of tests on yarns and fabrics —both untreated and varnished.[4,5,6] As a result of this work considerable improvements have been made in the cotton materials now used in the electrical industry, and the British Engineering Standards Association has been thereby enabled to issue recently a British Standard Specification on Varnished Cloth sheet, strip, and tape (BSS. 419–1931). Similar work has, of course, been going on in other countries, the American Society for Testing Materials dealing with this in the U.S.A.[7,8,9,10]

Table V
Average Properties of Typical Varnished Cloths

Colour ...	Yellow		Black	
Type of varnish ...	Clear Vegetable Oil		Oil-bitumen	
Thickness ...	·007 in.	·010 in.	·007 in.	·010 in.
Electrical Properties				
Electric strength (minute value) in volts/mil				
(*a*) At 20° C ...	780	820	900	950
(*b*) At 90° C ...	550	600	700	750
(Note—Electrodes are brass cylinders 1½ in. and 3 in. dia.)				
Sustained electric strength (Everest test), highest maintained stress, volts/mil.				
(*a*) At 20° C. ...	250	270	290	300
(*b*) At 90° C. ...	70	85	80	90
Mechanical Properties—				
Bursting strength (lb./sq. in.) ...	12·5	13·0	12·5	14
Tensile strength (lb./in. width)—				
Warp ...	40	45	50	50
Weft ...	30	35	40	40
Tearing strength (oz.) double tear—				
Warp ...	16	18	16	18
Weft ...	20	20	20	20
Ageing. Effect of heating at 110° C for 24 hours—				
Reduction of tearing strength ...	50%—60%		45%—50%	
Reduction of bursting strength ...	45%—50%		40%—45%	
Chemical Properties—				
Effect of insulatng oil ...	None		Slightly affected	
Effects of acids and alkalies ...	Slight		More resistant than yellow	

Moisture absorption is undoubtedly the feature which most seriously limits the use of cotton goods for insulation purposes. Evershed[11] in 1914 investigated the effects of moisture on the insulation resistance of cotton, and noticed particularly the hysteresis phenomena on absorption and desorption of moisture by absorbent cotton and other insulations. These adsorption hysteresis and allied effects have been studied and discussed very fully by Urquhart, Williams, and Peirce of the B.C.I.R.A.[12,13], and this work is of importance in considering the mechanism of adsorption in cotton and similar absorbent products. As far as these phenomena affect the electrical properties, however, the subject has been dealt with fully in work carried out to study means for improving the resistance

of cotton to the conduction of electricity under damp conditions. These researches have particularly brought to light the importance of washing, scouring or otherwise processing cotton yarns and fabrics to remove electrolytes and other deleterious substances before they are used for electrical purposes. The first work on this was carried out at the Shirley Institute in 1923, two memoirs on this subject being issued to members of the B.C.I.R.A., in 1923 and 1925, describing the technique of testing yarns for conductivity, and indicating methods of treating cotton products to improve their insulation resistance when damp. This research, carried out in collaboration with the E.R.A. and the Metropolitan-Vickers Electrical Co. Ltd., is referred to by Maxwell and Monkhouse in a paper before the Institution of Electrical Engineers[14] in 1925. This work focussed attention upon the desirability of cleansing cotton products from deleterious electrolytes, and other water soluble and chemically active substances which may cause troubles such as corrosion of metals, or tendering of the cotton when heated. Similar work on reducing conductivity in textiles was carried out more recently in America; mainly by Murphy and Walker.[15]

The effect of heat is of utmost importance, as already indicated when considering the uses of cotton products in electrical apparatus. Machines, transformers and other plant generally operate at elevated temperatures, owing to the heat developed by losses in windings and magnetic cores, and, in fact, the total output or rating of such machines is fixed mainly by the maximum temperature at which it is safe to operate them. As, however, it is the organic insulation materials which are liable to deteriorate most rapidly due to heat, this safe temperature limit, and, therefore, the maximum rating, is decided by their ability to withstand heat without undue ageing. Considerable research work has been done on this subject, chiefly by the electrical industry itself, attention being paid especially to the effect of heat on *mechanical properties*, as it is realised that failures of insulations, particularly in rotating machines, are in most cases primarily caused by mechanical rupture, usually as the result of depreciation of strength from heating, vibration or chemical action. In 1904 and 1905 extensive tests were made at the N.P.L., and in various electrical works, on the effect of heating common organic insulating materials such as papers, press-sphan, cotton tapes, canvas, linen and silk, some being varnished or otherwise treated. As a result of this work it was found that some of these products began to deteriorate at temperatures above 75° C., this being rapid at 125° C., although cotton coverings on wires showed no serious alteration up to 125° C.; and, in consequence, recommendations were made that the *highest* temperature which should be permitted with safety for insulating materials of this type is 115° C. at the hottest spot. Later, as the result of experience, the safe limit for untreated cotton and other fibrous materials was reduced to 100° C., and the British Engineering Standards Association fixed upon certain limits for the maximum allowable temperatures of machine coils, transformer windings and other electrical apparatus. Thus most machines using these insulations cannot, with safety, be loaded beyond the point which gives the standard temperature limit, and they have to be designed so as to prevent the temperature rising beyond this, such as by making the copper conductors of adequate size. Similar conditions prevail for apparatus, such as transformers, working in mineral insulating oil, but higher temperatures are allowed in consequence of the materials being immersed in oil. Engineers are constantly striving to obtain insulations which will work safely at higher temperatures, recourse having to be made to mica and asbestos for machines operating at 120° C.or over. It would, therefore, be of great advantage if cotton products could be made which would safely withstand temperatures higher than those now allowed for this type of insulation, as the life and reliability of electrical machines and apparatus could be improved and they could possibly be made smaller for the same horse-power.

Ageing tests are regularly made upon cotton insulating tapes and cloths by tensile, tearing, bursting strength and flexibility determinations, before and

after heat treatment of samples at, say, 110° C. in air and in oil. These tests often show up poor quality cotton and unsuitable finishing processes that leave chemicals in the textiles which tender the cotton when heated.

Thermal conductivity is also a matter of some importance, as the heat generated in wires and bars insulated with cotton textiles has to pass through these (which completely surround the conductor) before it is dissipated to the cooling medium.[16]

The mechanical tests usually carried out on these cotton products are—tensile strength, for which the E.R.A. have recommended constant rate of *increase of load* in preference to constant rate of traverse of one testing jaw; extensibility under load; tearing strength parallel to the threads (double tear method); bursting by air pressure on a disc 7 inches diameter, as for aircraft fabric; and other special mechanical tests are sometimes made. The Flexometer method[17] of comparing quantitatively the stiffness or flexibility of tapes and cloths is now being utilised particularly for the varnished fabrics. Ballistic methods of testing are now being adopted, and impact tests, with Izod machines, are important for the resin-bonded fabric boards.

Electrical tests of various types are, of course, indispensable for the varnished and bonded-fabric insulations. Insulation resistance, dielectric loss and permittivity tests are frequently made, and electric strength (breakdown voltage) tests are made on a routine basis as well as for research. A very important special test, to determine the ability of varnished cloths to withstand high electric stresses for long periods as in service, has been developed and used by A. R. Everest[18] in the laboratories of the British Thomson-Houston Co. Ltd., and has been adopted by the B.E.S.A. in BSS. 419–1931.

Special attention has been paid in recent years to electrical tests on materials under moist, hot and other conditions simulating those met with in service, especially with mechanical stresses applied before or during the tests, e.g. electric strength tests on tapes extended by tension.[3] (See BSS. 419–1931, Appendix III.)

Various chemical tests to determine acidity, presence of inorganic salts, etc., are in regular use, the most important being the *p*H tests. Viscosity determinations of cuprammonium cellulose solutions are also being adopted for checking the ageing of cotton products.

Table VI

Properties of Typical High Grade Synthetic Resin Bonded Cotton Fabric and Paper Boards

Properties	Synthetic Resin Bonded Cotton Fabric Boards	Synthetic Resin Bonded Paper Boards
Density (grms. per c.c.)	1·39–1·56	1·2–1·5
Density (oz. per cub. in.)	0·8–0·9	0·7–0·8
Tensile strength (lb. per sq. in.)	11,000–16,000	10,500–17,000
Shearing strength (lb. per sq. in.)	15,600–23,000	14,300 .
Compression strength (lb. per sq. in.)	25,000–35,000	16,200
Impact strength (ft. lb.) (cross-section of specimen ½ in. × $\frac{15}{16}$ in.)	4·2–7·9	4·5–10·0
Brinell hardness	48	50
Electric strength (minute value, volts./mil.)—		
0·125 in. thick at 20° C.	176–320	Up to 560
0·125 in. thick at 90° C.	70–130	170–350
Electrical breakdown along laminæ in oil (kv. per in.)—		
At 20° C.	62	15–65
At 90° C.	15·4	10–35
Surface breakdown in air (kv. per in.)	18–20	20·5
Surface breakdown in oil (kv. per in.)	20–22	24·0
Water absorption (24 hours), per cent.	0·6–4·0	0·3–1·0
Effect of hot oil (24 hours at 110° C.)	Absorbs 1·5 to 4·0 per cent.	Unaffected

FUTURE DEVELOPMENTS

The continuance and extension of the successful use of cotton products for electrical purposes naturally depend first upon *quality*, as the technical requirements are becoming more and more severe. Greater care in the manufacture of yarns and fabrics, with improved maintenance of *uniformity*, are especially necessary, and more inspection, testing and technical control, combined with more exact knowledge and understanding of these requirements, will undoubtedly be the greatest helps to progress. It is of course important that in striving for better products the financial side be not neglected, but this is generally controlled automatically by competition, and the increasing use of specifications and testing ensures the best value for money being obtained. Research is now being intensively directed to improving the resistance of cotton textiles to heat, moisture, fire, bacteria, and various electrical, mechanical and chemical influences, and this will undoubtedly improve their reliability, create more confidence in them and cause more extensive applications of these products in electrical fields. The more pressing and immediate problems are, however: the cultivation and selection of suitable fibres; the development of finishing processes which will render the cotton more moisture-resistant and able to withstand higher temperatures without undue stiffening and tendering; means of improving thermal conductivity and fireproofness without reduction of electrical and mechanical properties; reduction of the differences of mechanical strengths in warp and weft directions to give greater uniformity of cloths; and the general improvement of fabrics required for varnishing, so as to enable more uniform and reliable varnished cloth insulations to be produced.

CONCLUSION

It will be seen from the foregoing that cotton textiles have important and extensive applications, as primary insulation and non-conducting mechanical supports in electrical apparatus of all descriptions, and a great deal depends upon the characteristics of these products, especially the maintenance of the important properties under manufacturing and service conditions.

Considerable research work has been going on for many years on both fundamental and the more practical problems, which have enabled a fuller understanding of the essential features and characteristics of cotton fibres, yarns, and fabrics to be obtained; improved methods of manufacture of both cotton products and special electrical insulations embodying these; more economic utilisation of such materials in electrical machinery and other apparatus, resulting in greater reliability and better performance of these in all branches of electrical engineering, from domestic appliances to power station generators.

There is a great deal still to be done both by the textile and electrical industries, as under the intensive economic stress of modern industrial conditions, it becomes increasingly necessary to use materials more efficiently and effectively. The employment of cotton products for electrical purposes is by no means decreasing, though the form in which they are produced is ever changing, so that by still further co-operation between these industries in concentrating upon these problems, developments are sure to result which will be of mutual benefit.

ACKNOWLEDGEMENTS

The author wishes to express his indebtedness to the British Thomson-Houston Co. Ltd. for the loan of samples, lantern slides and particularly for permission to utilise data arrived at in their Engineering Laboratory. Thanks are also due to other firms, namely, The London Electric Wire Co. and Smiths Ltd., and The Universal Winding Company for valued assistance, and to Dr. A. B. Everest for the loan of lantern slides.

The author would also like to take this opportunity of expressing appreciation of the valuable assistance and co-operation of the British Cotton Industry Research Association, and the Research Department of the Bleachers' Association,

in the numerous problems which have arisen from time to time in the utilisation of cotton products for electrical purposes.

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The Chairman, Mr. W. Howarth, introducing Mr. R. I. Martin, who delivered the above lecture, said he expected Mr. Martin to treat the subject from the point of view of an electrical engineer. It was still looking a long way ahead to anticipate the general use of electric power. He thought the subject a very interesting one and, reviewing the developments which had taken place in the last 40 years, he felt it was up to everyone to encourage the visions of youth because they were a splendid driving force.

At the close of the lecture Mr. Howarth said he considered that a very complicated subject had been dealt with in a most competent manner. It had made him realise, and probably many of those present, how much destruction could be wrought in insulation from the use of faulty cotton. One had to strive to secure the use of the best when considering the electrical side of the industry.

A question was asked as to the use of textiles other than cotton for insulation purposes, with particular reference to the insulating powers of cellulose acetate yarns and fabrics compared with those of other textiles.

In reply the Lecturer said that had he dealt with the subject on these lines, it would have made his lecture two or three times as long, and therefore he had confined himself to cotton textiles.

Mr. Kershaw said it gave him great pleasure to propose a vote of thanks to Mr. Martin as he had worked in close co-operation with him for several years. He would like to urge that more specifications were drawn up and issued by B.E.S.A. for the production of unvarnished materials for insulating purposes.

He referred to the good work done in the researches of the Shirley Institute on these materials.

Mr. F. P. Slater said he was very pleased to second the vote of thanks. So far as he could see the electrical industry had gone in largely for cheapness, and he felt it might not be worth while spending a great deal of money in research on cotton textiles if the best materials available were not called for by the engineer. In the past, progress from the cotton end had been held up from economic reasons. He would like to be assured that it was worth while, especially from the research worker's point of view, to pursue the subject. He had nothing but praise for the comprehensive survey of the subject given by Mr. Martin, and most heartily endorsed Mr. Kershaw's remarks and vote of thanks. The vote was cordially given and Mr. Martin suitably responded.

WOVEN FABRICS AND YARNS

Over £150 in Prizes awarded by the Textile Institute

The awards in connection with the current year's competitions of this Institute are as follow—

(A) COMPETITION (Crompton Memorial)—WOVEN FABRICS

Equal First Prizes (each £30 and Certificate)—H. Schofield (Nelson Municipal Technical School) and A. Johnson (Leeds University).

Equal Third Prizes (each £15 and Certificate)—K. Nicholls (Bradford Technical College) and James Wild (Manchester College of Technology).

Prizes of £5 each—J. F. Levers (Blackburn Municipal Technical College), J. North (Bradford Technical College), and John Wild (Colne Municipal Technical School).

(B) COMPETITION—NOVELTY FOLDED YARNS

First Prize (£7)—B. Crossland (Bradford Technical College).

Second Prize (£5)—J. F. Levers (Blackburn Municipal Technical College).

Third Prize (£3)—A. E. Hyam (Blackburn Municipal Technical College).

(C) COMPETITION—NOVEL WOVEN FABRIC

First Prize (£10)—E. W. Wood (Dewsbury Technical College).

Second Prize (£5)—J. North (Bradford Technical College).

Equal Third Prizes (each £3)—F. Howard (Dewsbury Technical College), H. Jennings (Batley Technical College), J. Priestley (Huddersfield Technical College).

(D) COMPETITION—WOVEN FABRICS (Special Students)

First Prize (£5)—J. H. Lee (Burnley Municipal College).

Second Prize (£3)—J. Dunn (Keighley Technical College).

Equal Third Prizes (each £2)—S. Lee (Bradford Technical College) and S. Bairstow (Keighley Technical College).

The Adjudicating Committee of the Institute reports that although the number of competitors in the major competition, which demands specimens representative of several groups of fabrics, is not quite up to the average, yet the general level of attainment is distinctly high. The uniformly high merit was such, in fact, that reapportionment of the prize awards had to be effected and the total prize money increased. Improvement is most marked in small-scale design, subtle harmonies being successfully experimented with in many instances. In designs of bolder character—for upholstery, table covers, etc.—originality is not quite so pronounced. As to the costing of certain cloths, several competitors failed to provide calculations in complete form.

The competition for novelty folded yarns produced many attractive specimens, and in certain instances competitors have successfully achieved the presentation

of a number of well-defined types, which is of more importance than the offer of several examples of somewhat similar type.

The special competition for a woven fabric of novel structure produced the largest number of exhibits yet recorded, and the whole collection is noteworthy from the point of view of effective choice of yarns.

Throughout the competitions, the participants generally do not present adequate statement of claim in regard to the novel or other special features and intended purpose of the specimens submitted. In the conditions for next year's competitions, the Committee propose to insert suitable clauses to cover this requirement.

The presentation of prizes will take place at the Institute, Manchester, on the afternoon of Saturday, 5th December, and on the previous day (Friday, 4th December) the specimens will be on exhibition.

NOTES AND NOTICES

Institute's Annual Competitions

The annual distribution of prizes awarded in connection with the Institute's Competitions for the current year in respect of Woven Fabrics (Design and Structure) and Yarns, produced by advanced students at the various technical colleges and schools, has been fixed to take place at the Institute headquarters premises, Manchester, on the afternoon of Saturday, 5th December. The amount of prize-money to be awarded this year exceeds £150. Although the number of participants in the chief competition—that for the Crompton Memorial Fund prizes—is not quite up to the average strength, yet the general high level of merit was such that the adjudicators were compelled to readjust the amounts of prize-money and to increase the total amount awarded. The exhibits will be displayed on the occasion of the presentation of the prizes and they will be publicly shown on the day previous—Friday, 4th December. The Committee in charge of the Competitions Scheme have, for many years past, maintained a progressive policy with regard to the conditions attached to the competitions. In regard to the prospectus for 1932, further revision was suggested at last meeting of the Competitions Committee and it was decided to hold a special meeting on Friday, 27th November, for the consideration of the details of the programme.

Second Institute Scholarship

Under the terms of the special grant to the Institute by the Cotton Trade War Memorial Fund and the Cotton Reconstruction Board, the second scholarship to be awarded under the scheme was confirmed at last meeting of the Council of the Institute. The award was in favour of William Graham, of Blackburn. Receiving evening technical instruction at the Blackburn Technical College, this successful candidate gained many distinctions. He has already left his ordinary occupation as an automatic loom weaver and entered upon his full-time courses of study under the Scholarship at the Manchester College of Technology. The first holder of the Institute Scholarship, Alan Ratcliffe, of Walkden, near Manchester, has entered upon his second year work at the college named and the official report as to his efforts in 1930 has been accepted as highly satisfactory by the Institute Council.

Federation of Textile Societies

At a meeting of the Committee of Management of the above-named organisation held at the Textile Institute, Manchester, on Saturday, 14th November, the arrangements for the next Annual Meeting and Conference of the Federation were considered. The date of the event, 7th May 1932, was confirmed. The

event will take place at Bradford by kind invitation of the Bradford Textile Society. Mr. E. M. Roberts, representing the Society named, outlined the arrangements contemplated and the Chairman of the Committee, Mr. J. Burgess (Ashton-under-Lyne), expressed appreciation of the steps already taken by the inviting society. It was announced at the meeting that Mr. W. Munn Rankin, M.Sc., Principal of the Burnley Municipal College, would be nominated by the Burnley Textile Society for election as President at next Annual Meeting, to succeed Mr. J. W. Wolstenholme, of Rochdale. It was reported that the number of organisations now in membership of the Federation is 35, and that the newly-formed Belfast Textile Society was applying for membership.

Textile Institute Diplomas

Election to Fellowship has been completed since the appearance of the previous list (*September* issue of this *Journal*).

FELLOWSHIP

HAIGH, Ernest Varley (Manchester).

Institute Membership

At the *October* meeting of the Council the following were elected to membership of the Institute—R. Bleasdale, 14 Gisburn Place, Blackburn (Laboratory Assistant); P. S. Cox, 35 Chapel Street, Brierfield, Lancashire (Student); James Fairclough, 26 Bowker Street, Higher Broughton, Salford (Asst. to Buyer in Whites Department); Walter Farrar, 53 Burnley Road, Blackburn (Asst. Winding Overlooker); J. A. Hankinson, 71 New Park Road, Salford, Manchester (Asst. in Weaving Department); Jim Hulme, 97 Crescent Road, Dukinfield (Weaving Manager's Assistant); Wm. Pickup, 36 Rose Lane, Deepdale, Preston, Lancashire (Cotton Technician); W. J. Savory, 47 Douglas Street, Derby (Chemist Dyer); W. H. Towle, Mountfields, Forest Road, Loughborough (Assistant at Hosiery Manufacturers); Paul D. Vincent, 17 Old Kiln Lane, Bolton (Research Department); G. White, 69 Stanley Road, Bolton (Manager's Assistant)

At the *November* meeting of the Council the following were elected to membership of the Institute- R. C. Boyce, "Eastrop," 147 Ashby Road, Loughborough; M. V. Campbell, "Dilkhusa," Beauchamp Avenue, Kidderminster (Head Dyer); E. G. Cubbin, "Harewood," Woodgates, Rothley, near Leicester (Trainee); A. H. Gentle, "Hill Close" Spondon, near Derby (Textile Designer); D. C. Gwillim, 49 Mill Street, Barwell, Leicester (Hosiery Manager); D. Leuty, "Boxworth," 36 Slater Avenue, Derby (Foreman, Hosiery Dyeing and Finishing Department); N. P. Newsholme, "Oakfield," Utley, Keighley (Asst. Manager, Spinning Department); F. C. Price, "Everleigh," 38 Wilmot Street, Heanor, via Nottingham (Hosiery Examiner).

REVIEWS

Handbuch des Zeugdrucks. Part IV. By. G. Georgievics, R. Haller, and L. Lichtenstein. Leipzig: Akademische Verlagsgesellschaft m.b.H. (pp. xx + xvi + 1,240, with three large tables and 70 pp. of patterns).

The final part of this work (containing the contents, tables, and indexes for the whole book) shows no diminution in the quality of its predecessors (see this *Journal*, April 1929, p. 96; Sept. 1929, p. 161), and brings to a fitting conclusion the most exhaustive treatment that has ever been received by the intricate subject of textile printing. An interesting section on "Pigment and Metal-powder Printing," by R. Dax, reveals the great ingenuity which has been exercised in exploiting the permutations of inorganic and organic pigments, metal powders, wool, cotton, and other finely comminuted substances on the one hand; and of oils, albumin, cellulose ester solutions, and similar other vehicles on the other. In the attached patterns there is one example of a table damask design, reproduced by printing untinted cellulose acetate paste, which requires careful

examination to convince one that the design is not indeed woven. Near by are some spectacular metal prints on velvets, etc., and a very beautiful example of spray printing. A long section on "Finishing," by O. Gaumitz, surveys the subject in an extensive fashion, and is followed by articles on wool and silk printing; mordant prints (with, as is natural, an adequate treatment of the natural dyestuffs and a fine display of Paisley designs); and, finally, a section upon the origin of faults in the fabric occurring during the printing and finishing processes. This last article, by Prof. J. Savanovits, makes attractive reading. He does not seek so much to give exhaustive details of the diagnostic methods as to inculcate a commonsense and systematic approach to the problems which present themselves. There are simple schematic divisions of the common tests for the various types of materials, set out as large tables, and a long collection of references to original papers. F.S.

The British Colour Council: Spring Season Colour Card 1932; and Spring Season Wool Colour Card 1932.

These copyright cards are attractively produced and contain 60 and 40 shades respectively, generally of a rather more striking character than in previous issues. Inquiries made from distributors, producers, and colour makers rather point to insufficient use being made of these carefully selected ranges of shades. At the same time it is noteworthy that several leading firms, both distributors of coloured textiles and producers of the same goods, are now issuing a card periodically in substitution of their own shade cards, and doubtless this lead will be followed by the smaller independent firms when they fully realise the considerable saving of both time and expense which this procedure means to them. The production of a pattern card, however modest, in most small concerns is an event of importance and entails an amount of time, thought, and expense entirely out of proportion to its value to the producer in most cases. The textile producers of this country are slow to adopt any new idea until they are convinced that the innovation is likely to be of considerable benefit, and from the investigation carried out it appears that the points outlined above have not been fully considered by the trades concerned. If a suggestion might be made to the British Colour Council, co-option of feminine opinion before the production of the next issue would probably result in an improvement of the ranges and the cutting out of dead wood. J.R.S.G.

Physikalisch-technisches Faserstoff-Praktikum. By Prof. Dr. Alois Herzog and Dr. Erich Wagner. Published by Julius Springer, Berlin, 1931 (pp. viii+145+21 loose tables in pocket, 15 Marks.)

This volume is a combination of laboratory manual and reference book containing tables of the physical-chemical constants of fibres, in addition to which many of the tables and formulæ are given again in the form of loose graphs and nomograms carried in a pocket in the back cover. The first part of the book is arranged as a series of selected practical exercises, of which the 43 examples given cover textile microscopy, and chemical, physical-chemical, and physical methods. In each of these the problem is stated, the apparatus required is indicated, the technique is described, and finally the working out of an example is shown. The treatment of the material is both concise and lucid, and should enable any one with a general knowledge of the subject to follow the experimental technique quite readily, though naturally with such a wide range of subjects packed into 43 examples, only the more important methods could be selected and, inevitably, opinions would differ as to which is the most desirable selection. Yet it certainly seems a pity that no reference is made to the methods or data of the viscosities of cellulose materials in cuprammonium solution. The tables of data contained in the second part of the book are extremely valuable, since many of these have never been collected together in one volume before, and especially to English readers, since the major portion of them has been collected from journals which are not readily accessible in this country. A very wide field is covered and includes a list of chemical reagents with their uses in fibre investigations, summaries of the chemical behaviour of fibres, the dimensions, strength, moisture content, ash content, refractive indices, specific heat, specific weight, heat conductivity, and so forth of fibres, as well as more technical data such as twist constants, conversion data for different systems of yarn counts, and weights and measures. Certain of the data and the calculations embodying them lend themselves to

graphical treatment, as, for example, the conversion of yarn counts, whilst many of the calculations involved in the methods given in the first part of the book also lend themselves to a similar treatment, and these are also represented in the nomograms given in the pocket at the end of the book. Graphical methods save a great deal of time in making calculations, such as are used in textile investigations, where the degree of accuracy required is not too high. However, in spite of this, they have been neglected very largely, so it is all the more interesting to find such wholehearted use of them as is the case in the volume under review. A minor criticism is that the sources of data are not given, beyond the names of the authors. However, a more serious criticism of the book is that there are no indices, so that its use as a work of reference is prejudiced by the waste of time involved in finding the particular information required. The contents table at the beginning is a very inadequate substitute for an index, and it is to be hoped that the authors will rectify this defect in future editions. J.M.P.

Lancashire and the Far East. By Freda Utley. Published by George Allen and Unwin Ltd., London. (Pp. 395, 16s. net.)

The first impression of the reader of this book will be one of admiration for the industry and energy which the author has obviously applied to the collection of her material. A closer study of the book, however, may raise doubts as to the reliability of some of the sources from which the evidence is drawn. We are told, for example, that in compiling particulars of Japanese production and costs, Miss Utley was careful to obtain her information in a roundabout way. Details of production were obtained from the engineer, numbers employed from the manager and her own observation, wages paid from another member of the staff, and so on. The Lancashire reader will naturally ask himself whether he would feel safe in calculating the cost of a Lancashire mill from information gathered in this way. Miss Utley has certainly gathered together an impressive array of statistics. It is, of course, possible to find figures which will support almost any argument. The duty of the statistician and economist, however, is to shape theories to suit facts; not the reverse. It is, therefore, rather alarming to find on different pages, supporting differing arguments, these three passages, ". . . the Indian mills having practically a monopoly in yarns below 30's," ". . . hand-loom weavers mainly use imported yarn," and "The usual type of hand-woven cloth is made of yarns of counts 7's to 20's." Fortunately, Miss Utley shows quite early in the book the direction in which she wishes to lead the reader. Lancashire will be surprised to learn, from page 72, that "The standard of living amongst Lancashire cotton workers is terribly low. . . . the clothing of both men and women is terribly poor . . . Their homes are bare of the first necessities of life." Miss Utley has, of course, undertaken an admittedly difficult task in trying to contrast Lancashire and Japanese costs of production. Experienced investigators know the difficulty of even obtaining a strict comparison between two Lancashire mills. Pounds of yarn, even when of the same count, are not like peas in a pod. They can be distinguished one from another. Miss Utley, however, appears to have been aided by a refreshing innocence of commercial practice. We read on page 53, for example, referring to Lancashire costs, " . . . the cotton broker takes ½ per cent., the yarn agent 1 per cent., and the cloth agent 1½ per cent., whilst in Japan this combined 3 per cent. on prices is eliminated. . ." It does not seem to have occurred to Miss Utley that these different percentages are based on different amounts, and that if they were all based on the selling price of the finished article, their total would be very much less than 3 per cent. One naturally wonders whether her conclusions as to Japanese costs are based on similar misconceptions. Apart from the conclusions of the author, however, this book would still be a valuable work of reference if the reader could feel sure that the energy expended in compiling the information had been matched by care in checking the figures. A statement on page 77 that Japan has 86,000 hand looms and one on page 181 that in 1927 there were 99,684 hand looms in Japan, raise doubts, however, which receive support from other parts of the book. For example, on page 286 is a table giving the consumption in India of machine-made cloth, calculated from home production, imports, and exports. Unfortunately, Miss Utley has neglected to take account of exports by land, which are not inconsiderable. Even the statistics, therefore, can hardly be used safely except by those who have access to the original sources. R.W.L.

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PROCEEDINGS

Examination in General Textile Technology

An examination in General Textile Technology in connection with applications for the Associateship of the Textile Institute took place at Headquarters, Manchester, and simultaneously in London, Glasgow, Nottingham, Bombay (India), Mt. Gambier (S. Australia), Buenos Ayres, and Sao Paulo (S. America). For the information of members and others interested, the examination paper, in two parts, is published hereunder—

PART 1 (SECTIONS I AND V OF SYLLABUS)

10 *a.m. to* 1 *p.m.—9th December* 1931

Candidates to answer THREE out of FOUR Questions in each Section of Part I

Section I—Fibres and their Production

(1) With reference to its physical properties, state why flax may be considered superior to cotton for the following purposes—Sheetings; aeroplane wing fabric; table napery; face towels; glass cloths.

(2) What is meant by the term "quality" as applied to wool, and how is it assessed? Discuss quality in relation to length, diameter, and crimpiness of the fibres.

(3) Artificial humidification is not equally indispensable for the successful manipulation of all types of fibre. Discuss the relative sensitivities of the main textile fibres to humidity conditions, and state in each case where artificial humidification is necessary and why.

(4) Write a short essay on flax production in Europe, describing the general character of the fibre produced in the areas you mention.

Section V—Analysis and Testing of Raw Materials, Yarns, and Fabrics

(1) State what you understand by the following terms—Breaking strain; elasticity; extensibility; stress-strain diagram; moisture content.

(2) Suggest some method by which you could measure the angle of twist in a yarn.

(3) You are asked to examine a fully bleached cotton garment which shows excessive wear after repeated laundering. With a sample of the original material in your possession, how would you proceed to determine whether the laundering was responsible?

(4) What are the factors which determine the manner in which the threads break down in the lea or skein test? What precautions should be taken to make the latter as satisfactory a test as possible?

PART 2 (SECTIONS II, III, AND IV OF SYLLABUS)

2.30 *p.m. to* 5.30 *p.m.—9th December* 1931

Candidates to answer TWO out of THREE Questions in each Section of PART 2

Section II—Conversion of Fibres into Finished Yarns

(1) Briefly describe the processes necessary to convert raw wool into (*a*) woollen yarn, (*b*) worsted yarn.

(2) What advantages have doubled yarns over single yarns? Name the particular purposes for which doubled yarns may be used advantageously.

(3) Trace the evolution of the spinning frame and give a brief account of later developments, illustrating by reference to any particular fibre.

Section III—Conversion of Yarns into Fabrics, and Fabrics produced by Special Methods

(1) Under what circumstances is it advisable to use two or more warp beams in the process of weaving? Give two examples of typical fabrics for which two or more beams are essential.

(2) Sketch and describe any one method employed in weaving machinery for controlling the interlacing of warp and weft threads.

(3) Define the following terms used in the knitting industry—Gauge, wale, course, merino, wheeling and fingering yarns, latch needle, spring or bearded needle.

Section IV—Conversion of Fabrics into Finished Materials

(1) What do you understand by the term "finishing" in relation to textile fabrics? Describe any one method of finishing a fabric composed of either (*a*) silk, (*b*) wool, (*c*) cotton, (*d*) linen, or (*e*) artificial silk.

(2) Contrast the actions of caustic soda and sulphuric acid, each under varying conditions of concentration and temperature, on wool and cotton. Describe how the changes produced can be utilised industrially.

(3) What are the principal bleaching agents used for (*a*) cotton, (*b*) wool and (*c*) silk? Describe the application of one of them to piece goods.

ANNUAL COMPETITIONS OF THE TEXTILE INSTITUTE DESIGN AND STRUCTURE OF WOVEN FABRICS

The presentation of the prizes awarded in connection with the 1931 Competitions of the Institute was performed on Saturday, 5th December, at the Institute, Manchester, by Mr. Henry Binns of Bradford, Fellow, and Chairman of Council; an enthusiastic supporter of many movements associated with technical education in relation to the textile industries. Mr. Binns was introduced by Mr. John Crompton, Chairman of the Competitions Committee, who presided and welcomed the participants in the competitions and the representatives of various colleges and schools in attendance. He considered that the exhibits formed a highly satisfactory collection and he warmly congratulated the competitors generally. The task of the adjudicators had been difficult and in the principal competitions it was found impossible to separate the leading albums. Therefore, two equal first prizes and two equal third prizes were awarded. He was glad to note a growing tendency on the part of competitors to submit draping lengths of cloths and trusted that in future years this practice would be more generally adopted. It was far more satisfactory that lengths should be available for exhibition purposes.

Mr. Binns, who subsequently presented the prizes, said that after carefully examining the beautiful samples produced for the various competitions, three impressions were uppermost in his mind. Firstly, he felt great admiration for the designs and colours exhibited; secondly, he felt—the result of his experience as commercial traveller, no doubt—that he would like to be selling these fabrics; and thirdly, he was impressed by the effort put forth not only to produce the specimens, but in setting out their particulars and costings.

The Prince of Wales and Sir Francis Goodenough had repeatedly drawn attention to the needs of British industry in the matter of efficient salesmanship, both at home and abroad. He, the speaker, saw no reason for withholding from salesmanship the same careful consideration given to production. The same precision of measurement was not possible in both cases, but in salesmanship such precision was not, perhaps, necessary. In his opinion the general principles governing the exercise of judgment were already sufficiently clearly defined for commercial guidance.

Salesmanship did not admit of too much generalisation, and distinction must be made between the selling of electrical plant and of dress goods. Mr. Binns said he proposed to confine his remarks to the textile trade. In this industry, or collection of industries, certain groupings could be discerned.

Firstly, there were the Producers, concerned with processes from the raw material to the finished goods. In this field more and more accurate measurement was possible and a vast amount of special knowledge had been built up.

Secondly, there were the Retail Distributors and Consumers who sought to anticipate and supply the requirements of users of textile products. Consumers, in his opinion, developed judgment to some extent as a result of having money and as a result of experience in spending it.

Between these two groups was a less clearly defined group—Agents, Merchants, Garment-makers, and Wholesale Buyers. In this group occurred high development of what the speaker called "intuitional" judgment.

Broadly speaking, contact between producer and consumer is made by way of the commercial traveller to the retailer. He restricted the word "salesman" to individuals who sold commodities from one section to another within a group; the commercial traveller was the link between the main group of producers and the other main group of consumers. Thus the commercial traveller was

an intermediary between the technical knowledge and skill of the producer and the trained judgment of the retailer. The more he had in common with both groups the more efficient link he would be.

Mr. Binns then surveyed the chief functions of a commercial traveller. He must be able to retain old accounts and open new ones. He must sustain and create an emotional interest between his firm and their present and potential customers. This sounded perhaps simple, but in practice was often very difficult; to some individuals it was an impossible task. Correspondence and advertising, while valuable allies, could not supersede the individual contact.

Behind the representative's duty, said the speaker, was the firm's duty—that of supplying goods both smart in appearance and attractive in handle, and if to the superficial, intrinsic value can be added, competition can more successfully be met. With this duty was that of working upon courteous and efficient business methods.

Mr. Binns then stated that in his opinion the assumption that the technically-qualified man and the commercial traveller were distinct types and never combined in one individual, was erroneous. He thought that among the Associates of the Textile Institute a far-sighted firm might find ideal representatives in the commercial sphere. Such a qualified man, possessed of a good general education, of a general knowledge of textile technology, and of detailed knowledge of a specific section of the textile trade, and also some knowledge of applied science, could arouse interest in materials about which he was fully informed technically. Such well-qualified men, if put "on the Road" and given freedom, would no doubt enthusiastically add to their qualifications those others, such as languages, economics, and a knowledge of local customs, which it had been pointed out were sadly lacking in some of this country's overseas representatives.

He felt sure that the prestige of the British textile trade would increase in the world's markets in proportion as we were able to back our selling forces with intellect, knowledge, the power to sustain an emotional interest, and character.

On the motion of Mr. T. E. Mitchell (Rochdale), Chairman of the Lancashire Section of the Institute, seconded by Mr. H. Holroyd (Huddersfield), who attended as representing the Federation of Textile Societies, Mr. Binns and the Chairman (Mr. Crompton) were warmly thanked for their services. Visitors were afterwards entertained to tea, and inspection of the exhibits of fabrics and yarns proceeded until about 6 p.m.

In the evening, the exhibition was visited by members of the British Association of Managers of Textile Works, and an hour's entertainment was provided by Mr. Crompton, who, by means of the lantern and screen, showed a large collection of film records depicting scenery registered in the course of his recent world tour.

Mr. R. J. H. Beanland (Clayton West, Huddersfield), on behalf of the Council of the Institute, welcomed the Managers and their friends, and said he thought the visitors would agree that the exhibits resulting from the current year's competition were highly creditable and encouraging. The exhibits denoted real enthusiasm in relation to the branches of the industry with which the competitors were associated. Coming from Yorkshire, he was glad to find so good a proportion of the prizes were awarded to competitors in that county. Financial support for the Institute's Competitions had not yet been forthcoming from the wool interests, but he would like to assure Mr. Crompton that this matter was receiving earnest consideration. Indeed, he hoped that before another year passed this omission of support would be remedied.

Mr. Fletcher Chadwick, President of the Managers' Association, returned thanks for the cordial welcome and said the Managers greatly appreciated the opportunity afforded each year of demonstrating their interests in this particular branch of the activities of the Textile Institute which Mr. Crompton had so generously supported.

London Section

Meeting at the Clothworkers' Hall, Mincing Lane, E.C., on Tuesday, 10th November 1931; Mr. G. M. Canham in the chair.

RECENT DEVELOPMENTS IN THE STUDY OF WOOL FINISHING PROCESSES

The Chairman introducing the lecturer, Dr. J. B. Speakman of Leeds University, said he was sure the meeting welcomed Dr. Speakman and was anxious to hear his lecture.

Dr. Speakman said that he considered it a great privilege to speak to the London Section of the Textile Institute, and particularly was it a privilege to speak in the Hall of the Clothworkers' Company since the Company had behaved so generously to the Textile Department of the University to which he had the honour to belong.

Continuing, he said that his lecture would be an attempt to define the part played by the surface scale structure of the wool fibre in wool finishing processes. The scales were far more resistant to chemical and mechanical attack than the interior of the fibre, and for a fabric to possess the best wearing properties, it was essential that the scales should be preserved intact. It had recently been shown that wool was immune to attack by acid and alkali between *p*H 4 and *p*H 8, and for wool to remain undamaged during scouring, the operation must be carried out between these limits. The importance of this result became apparent when it was remembered that the maximum scouring efficiency of soap solutions was only realised at *p*H 10·7, while an 0·5% solution of soda had a *p*H of 11. It was possible to preserve wool intact through the scouring process by the adoption of suint scouring, the commercial scouring liquor being said to have a *p*H of about 7·7, within the stability region. Similarly, piece scouring could be made completely safe by the use of Igepon A, which dissolved in water to give a *p*H of about 6·5. Unfortunately, the milling process could only be carried out in relatively strongly acid or alkaline media and the full benefits of preserving the wool intact through the scouring processes would only be realised with worsteds.

The nature of milling shrinkage was next considered by the lecturer in detail because it was the most important of all wool finishing processes and because the ability of wool to felt had led to the development of an unshrinkable finish for hosiery goods. The method for measuring the scaliness of different wools was outlined and it was shown that no perfect correlation existed between scaliness and milling power. Although the scales were directly responsible for the occurrence of milling shrinkage, other factors played a part in determining the relative milling properties of different wools. Experiments were quoted to prove that, other things being equal, increasing fibre length and fineness would be accompanied by increased rates of milling. Attention was next directed to the fact that the rate of shrinkage of a fabric under defined milling conditions increased with increasing acidity or alkalinity of the milling agent. Experimental data for hydrochloric, sulphuric, and acetic acids were quoted and it was shown that the swelling of wool fibres also increased with increasing acidity or alkalinity of the milling agent. On the other hand, it was shown that the rate of shrinkage of wool

fabrics on a milling machine was at a *maximum* at about 43·5° C., whereas the swelling of wool fibres in water was at a *minimum* at about the same temperature. Thus as regards changing *p*H of the milling agent, the rate of shrinkage increased with increasing swelling, whereas with changing temperature, the rate of shrinkage increased with *decreased* swelling. This contradiction proved that fibre swelling played no direct part in milling shrinkage and some other factor must be sought in its place. This was the *ease of extension of the fibre.* Increasing acidity, alkalinity, and temperature all make fibres easier to stretch and, further, there was no difficulty in visualising how ease of extension might facilitate milling shrinkage. The theory developed was a combination of the views of Arnold and Shorter but it remained to show why milling shrinkage should take place most rapidly at 43·5° C. when fibres became increasingly easy to stretch at temperatures up to 100° C. The reason was that not only must a fibre become easier to stretch for milling to take place rapidly, but it must also retain a high power of recovery from extension. There was marked hysteresis between the processes of extension and contraction and its extent was at a minimum at about 40° C. Above this temperature, the facilitation of milling shrinkage by increasing ease of extension of fibres was opposed by increasing hysteresis between extension and recovery, with the result that a temperature of maximum milling was realised. From these experiments it became clear that two things were required of a fibre before milling skrinkage could occur: that it should possess a surface scale structure and that it should be perfectly elastic. The attempts which had been made to produce milling shrinkage with rayon fibres by giving them a surface scale structure were therefore misguided, because such fibres were remarkable for imperfections of elasticity. This discovery of the two-fold cause of milling shrinkage had an important bearing on the methods employed for imparting an unshrinkable finish to hosiery goods. Hitherto, all such methods had aimed at making wool unshrinkable by rendering the scales inoperative by means of chlorine or hypochlorous acid, but such treatment was accompanied by a marked reduction in wearing properties. There appeared to be no way of escape from the dilemma that hosiery goods were either defective because they shrink or because they possess inferior wearing properties, but it is now clear that there was a second way of making wool unshrinkable—by making it imperfectly elastic. There was no necessity to make this imperfection of elasticity permanent; what was required was that some agent should be added to the scouring medium which makes fibres imperfectly elastic while scouring was carried out, the reagent being removed during washing off and perfect elasticity then restored. In this way it would be possible to retain the high wearing properties of undamaged wool fibres without encountering the difficulty of excessive shrinkage, and the necessity for any unshrinkable finish would disappear.

The Chairman said he was sure that everyone present had appreciated the clear presentation of his subject that Dr. Speakman had given. He invited questions.

Mr. L. J. Mills (Fellow) asked what effect the scouring and milling processes had on carbonised wool, and whether the surface scales were damaged during the rag-pulling processes. He also wished to know what effect from the finishing point of view, the acid used in carbonising had upon carbonised wool. He took the opportunity of proposing a hearty vote of thanks to Dr. Speakman.

Dr. Speakman, replying, said recovered hairs suffered two ways. Pulled wool was short, and for shrinkage a long staple was required. Again during wear and during the tearing operation scales are worn off the individual hairs. Such hairs were possessed of little "life" and milling would necessarily be slow. The loss of scales would also reduce the wearing qualities of the ultimate fabrics.

Fabrics made from recovered wool had a tendency to crease easily and permanently. It was well known that carbonised wool was harsher in handle, and this might be due to the effect of the carbonising process on the wool scales.

The vote of thanks was seconded by Mr. A. Hardman (Associate) and carried unanimously.

YORKSHIRE SECTION ASSEMBLY AT BRADFORD

A social gathering of members of the Yorkshire Section of the Textile Institute took place at the Midland Hotel, Bradford, on the evening of the 19th November last. Mr. Arthur Saville, the Chairman of the Yorkshire Section kindly invited the whole of the members of the Section, together with a few friends, to an assembly arranged so that they could meet the President of the Institute (Mr. George Garnett of Bradford) and others. It was a gathering for the fraternisation of members. Several addresses were contributed and the proceedings took the form of a smoking concert. Mr. Saville introduced Mr. Garnett, and, in doing so, expressed the general sense of appreciation which prevailed as a result of Mr. Garnett's acceptance of the responsibility of the presidential office. Welcoming the large response to his invitation to that gathering, Mr. Saville said his object was to bring members together and, by this event, secure close contact with the President (Mr. Garnett), Past-President (Mr. John Emsley), Mr. Edford Priestley, and others. Mr. Garnett had been one of the warmest supporters of the Institute movement since its foundation and had thoroughly earned the distinction of election to the highest office. The name of Mr. John Emsley was indelibly associated with one of the most important movements ever undertaken by the Institute—The obtaining of the Royal Charter under which the Institute became authorised to award certificates of competency to the textile technologist and to conduct examinations in relation to such awards. In 1922, Mr. Emsley, as President, set himself the task of promoting a scheme of lasting benefit to the Institute and to the Industry, and so determined was he in the pursuit of the object that he remained in office for four years until the object was achieved. The scheme of granting qualifications in the form of Associateship and Fellowship had proved distinctly successful. It was gratifying to know that Yorkshire was taking a creditable share of these distinctions. To-day, there were 165 Fellows and 215 Associates and in these totals Yorkshire was represented by 40 and 45 respectively. In the matter of Institute publications, proposals were in hand for development. The importance of the Information Bureau of the Institute was being emphasised and inquiries, as to textile literature references, sources of supplies of various descriptions, and statistics, were increasing rapidly. Students of the various technical institutions were encouraged by the Institute's annual competitions in regard to design and structure of woven fabrics and several prizes were awarded this year to West Riding representatives. He urged all members to consider the Institute as their own organisation and he particularly welcomed the younger members, some of whom were Associates, because the future of the Institute would depend greatly upon their attitude to the movement.

Mr. George Garnett (President) thanked Mr. Saville for his welcome and hoped the gathering would result in the formation of many lasting friendships. The Institute had a great future before it, and if the spirit which had prevailed in the movement in the past, involving enormous devotion and self-sacrifice, was carried forward, a much higher position would be attained.

Mr. John Emsley congratulated Mr. Garnett on his election and he appealed especially to the young men for unwavering loyalty to the Institute.

Addresses were also contributed by Mr. Frank Hopkinson. Mr. Edford Priestley and Mr. T. Halstead, and, at intervals, songs were contributed.

Midlands Section

KNITTING MACHINE DEVELOPMENTS

The first meeting of the 1931–1932 Session took place at Nottingham in the Recreation Room at the premises of Messrs. I. & R. Morley. Mr. Thomas Morley, Chairman of the Midlands Section Committee, occupied the chair and introduced the Lecturer—Mr. J. Chamberlain (Fellow).

Referring to the fact that industries depended upon supplies of raw material, and upon machinery developments, the lecturer said that in the knitting industry machinery changes were constantly being made, and in his opinion this state of things was likely to continue. Ten years ago there were no 300-needle machines, nor were spring-needle hose machines using reciprocating needles in use; reverse plating on half-hose machines was unknown. Other machines, continued Mr. Chamberlain, were coming into use as a result of the stabilisation of the manufacture and supply of rayon. In a single decade the outlook had changed; development had taken place and improvements had been made. Mr. Chamberlain then proceeded to discuss developments, which were fundamental changes, and improvements, which do not involve such changes, in relation to the needle, the sinkers, the pressers, jacks, and points. He also outlined the two ways in which knitting machines may be developed. Firstly, by general developments applicable to several types of machine, and, secondly, by individual machine developments. In conclusion, a summary of these two classes of developments was given. Mr. H. F. Lilburn kindly supplied refreshments, during which an interesting discussion took place. A hearty vote of thanks to the lecturer terminated the meeting.

VISIT TO NOTTINGHAM LACE FACTORY

Members of the Midland Section of the Textile Institute to the number of twenty were privileged to pay a visit of inspection to the lace factory of Messrs. T. Birkin & Co. Ltd., New Basford, Nottingham, on the 11th November. Representatives of the firm conducted members over the various departments and explained both machinery and processes. Methods of warping, manufacture, and finishing were all considered and, after the factory inspection, the visitors were permitted to examine a complete range of exhibits of the firm's productions, including a large variety of made-up goods composed wholly or partly of lace. The exhibits included several replicas of articles supplied to Royalty or produced in connection with events of national importance. On conclusion of the inspection, Mr. Thos. Morley (Chairman of Midlands Section Committee) moved a hearty vote of thanks to the firm, and said that members were really grateful for the privilege so kindly conceded. His own interests applied to the knitting industry, but he regarded interchange of visits between allied interests as exceedingly interesting and desirable. Mr. J. H. Lester (Manchester) seconded the vote, which was heartily accorded, and Mr. Birkin suitably acknowledged the vote.

NOTES AND NOTICES

The Institute's Annual Competitions

The prospectus of Institute Competitions for 1932 is in course of preparation and will be issued to textile departments of colleges and schools early in January. The Competitions Committee have again given most careful consideration to suggestions received for revision of the requirements in regard to the various competitions, and the prospectus will be found to contain considerable modification of terms and conditions. In the case of the main competition—that which demands a collection of specimens of woven fabrics from each competitor—the number of fabrics required will be 16 instead of 20. An important provision fully retained, however, is that which refers to the variety of fabrics to be submitted. There will be no diminution of demand in respect of versatility. The "C" Competition, for Novel Woven Fabric, will be greatly amended with a view to providing increased scope. It is to be described as a competition in respect of Special Woven Fabric, and competitors will be required to produce a fabric for a definite purpose and present an accompanying statement of claim as to the merits of the fabric for the purpose specified. It is recognised that the range of fabric production has considerably expanded in recent years and, under the new conditions, competitors will be able to consider fabrics for industrial uses as well as for wearing apparel and domestic needs. The matter of framing a competition in relation to the design and structure of knitted fabrics has undergone careful consideration by the Committee of the Midlands Section of the Institute, and the inclusion of a competition for this branch of the industry in the prospectus for the coming year is contemplated.

Journal Development

The coming year, at least so far as the *Journal* of the Institute is concerned, promises to be well-defined. To date, three distinct periods can be seen in *Journal* growth. From 1910–1917 issue was spasmodic and, apart from a very comprehensive bibliography, largely compiled by the late Professor Myers, the volumes were mainly a record of Institute meetings. In April 1918 the *Journal* was placed upon a basis of regular monthly issue and its contents were divided into Proceedings, in which reports of meetings were recorded; Communications, which were records of original research; and Abstracts, in which current textile literature was summarised. The page size was changed from octavo to quarto and revenue from advertisements rapidly increased. During this period the Textile Industrial Research Associations came into being. Fuller co-operation on the part of Research Associations led to the inauguration of the third period of *Journal* development. In 1922 the octavo page size was resumed, on the advice of the Department of Scientific and Industrial Research, and the present-day sections of the *Journal* were established—viz. *Proceedings*, which embrace not only reports of meetings of the Institute but also Notes and Notices and Reviews of Books; *Transactions*; and *Abstracts*, these being almost entirely contributed by the Research Associations. The *Journal* was also constituted the official organ for the publication (as *Transactions*) of publicly-released Memoirs of the Textile Research Associations, and later was constituted its official organ by the Indian Central Cotton Committee. During this period marked development has taken place in all directions, circulation has quadrupled, the number of pages of matter published trebled, and the revenue from Advertisements and Sales more than trebled. In 1932 certain developments in the Proceedings are contemplated and it is expected that articles of a more "general" character will be published. Members should remember that when all is said and done the expansion of the Institute and its use to the textile industries rests with them and them alone. Any suggestions and/or offers of contributions will be welcomed and carefully considered.

The Institute Library

Members of the Institute, whose interest in this Note may be aroused, are requested to ask themselves whether they were aware of the existence of the Institute's Library, whether they could use it or whether they could supplement it ? During the past 12 months the library facilities have been utilised much more freely, and the Library Committee hopes this development will continue and increase.

The library is not by any means a large one, but its growth during the past three years holds out promise that it will ultimately achieve a magnitude of the order felt to be desirable by those in charge of it. It was commenced by gifts and exchanges of periodicals when the Institute began, and some of the first periodicals received are still coming to hand regularly. Unfortunately the foresight exhibited, in many directions, by the founders of the Institute does not seem to have been directed towards a library, and instead of possessing 21 consecutive years' issues of these periodicals it has to be recorded that they were destroyed. By gifts and purchases many valuable sets of periodicals have subsequently been built up, but in the main, publications of this type are not available prior to 1923.

The books section of the library is founded upon the collection of volumes made by the late Professor Fox which, at his death, was purchased and presented to the Institute. This collection was certainly not big but it was well-chosen and many items in it have, for long, been out of print. This collection was supplemented by additions from the library of the late Professor Myers, which enabled many gaps to be closed by books hitherto unprocurable. Though the Institute subscribes to certain periodicals, it rarely purchases a book. Gifts of small numbers of volumes and of single publications are constantly being made, and in this direction the Library Committee anticipates a regular series of additions. It is felt that many members do not yet realise that books, pamphlets, and periodicals which they may almost have come to regard as worthless, would be sure of careful consideration if offered to the Institute Library.

The main source of additions of books to the library is the "review copy." All publishers of note who issue books on textile or allied subjects now regularly submit copies of these works to the Institute for review. These books form a valuable source of annual growth. The periodicals and pamphlets library is regularly augmented by the regular exchange of such publications with the *Journal of the Institute*, and the list of these now contains over 200 names.

A further Section of the library is now being started—a library of Trade Catalogues—since librarians and others are realising how much valuable information for the technologist is, nowadays, often included in these publications. This Section is quite small at present, and gifts would be very welcome. A set of catalogues issued by any of our leading textile machinists, for example, over the past 50 years, would be invaluable.

It must finally be pointed out that a Library Catalogue is available—price 6d. post free—and that this has been supplemented once and will be again early in the New Year.

"On Coming-of-Age"

At the meeting of the Council of the Institute, in December, consideration was given to arrangements for the next Annual Meeting in 1932. This, naturally, brought to mind many recollections of the Annual Meeting in the current year and of those meetings and other events which were, collectively, the Celebrations of the Institute's Coming-of-Age. Portraits of celebrities "at the age of 3," "at the age of 15," and "at 21 years of age" were at one time popular with little or no apparent reason. It would appear to be a well-founded assumption that the history of a living, growing, and increasingly-valuable organisation, such as the Textile Institute, with portraits of those whose untiring energy and continued interest made the origin and growth of that organisation possible, would have

found ready sale among the members. It can hardly be said, yet, that this is so. The Council of the Institute hopes that the notice, issued with the *Journal* this month, will serve as an adequate reminder to members who have not already done so, that this record—"A Twenty-one Years' Chronology of Textiles"—is available and should be in the hands of every member. It may serve as some slight stimulus to know that one member contemplates presenting copies to his friends at Christmas.

Textile Institute Diplomas

Elections to Fellowship and Associateship have been completed since the appearance of the previous list (November issue of this *Journal*).

FELLOWSHIPS

LORD, Richard (Manchester).
SPEAKMAN, John Bamber (Leeds).

ASSOCIATESHIPS

CLARK, Irene (Nelson).
EDWARDS, Cyril Houghton (Nottingham).
NEWSOME, Henry Smith (London).
HEY, Charles Matthews (Preston).

Membership

At the December meeting of Council, the following were elected to Membership of the Institute—E. Clegg, 53 Lister Street, Accrington (Clerk to Chief Technical Superintendent); B. Crosland, "Chellow Nook," Shaftesbury Avenue, Bradford, Yorks. (Student); T. Fraser, 57 Victoria Street, Dunfermline, Scotland (Damask Designer); Wm. Graham, 1 Long Row, Mellor, near Blackburn (Student); F. Ibbetson, 5 Knowles Street, Dudley Hill, Bradford, Yorks. (Textile Designer); F. C. Johnson, 59 Spenser Road, Herne Hill, London S.E.24 (Wholesale "Linings Department"); H. Laithwaite, 313 Lees Road, Oldham (Assistant Spinning Overlooker); C. J. Lancashire, "Lynton," Cropston, near Leicester (Manager, Hosiery Trade); E. B. Millard, Massachusetts Institute of Technology, Cambridge, Mass., U.S.A. (Professor of Physical Chemistry); T. H. Morris, 77 Fountain Street, Manchester (Secretary, Cotton Spinning and Manufacturing Firm); J. H. Ratcliffe, 32 Nutter Road, Accrington (Loom Overlooker); W. T. Rigby, 19 Mansion House Road, Paisley, N.B. (Foreman Dyer); J. H. Riley, 2 First Avenue, Tottington, near Bury (Sales Manager's Assistant); Geo. Whitaker, 278 Swan Arcade, Bradford, Yorks. (Wool Merchant).

REVIEWS

Elementary Textile Design and Fabric Structure. By John Read, F.T.I. Published by Edward Arnold & Co., London. (5s. net.)

In his introduction to this elementary text book of some 100 printed pages, the author, who is the head of the Textile Department, Royal Technical College, Salford, and a Fellow of the Institute, very modestly states that the book has been prepared for the use of students in the elementary grades of fabric structure and textile design. The author is to be congratulated for breaking away from existing notions on the size of text books by producing a book on fabric structure which is of the same size as the well-known design point paper pads so widely used in technical colleges.

By the simple device of inter-binding nearly 30 full pages of design paper into the book, on which are provided more than 330 point paper designs, drafts, and lifting-plans of all the fundamental fabric structures, the author also provides innumerable examples which are purposely left incomplete, to afford students an opportunity to practice squared-paper designing in a most convenient form. By leaving the back of these pages blank, space is provided which will prove useful

for both practical and more advanced notes on points brought out by experience. In this manner this book becomes not only a text book and exercise book for students, but a useful desk log for those actually engaged in the industry. Seventy-two photographs of typical cotton cloth structures, in addition to the quality particulars of the different classes of fabrics, with their uses, are contained in the text. A separate chapter is devoted to each fundamental fabric structure and the variations possible in each structure are pointed out. The author adopts the term "weave plan" in place of "design," which seems to be more generally favoured in the industry. The book is very obviously the outcome of a long practical experience in the teaching of a difficult subject. The method of showing the peg plan might be open to criticism. This new text book should make a genuine appeal, not only to teachers and students of the subject, but to craftsmen engaged in weaving and to an ever-expanding circle of members of the Institute, each of whom is a specialist in some other branch of textile technology, but also desires knowledge in this important subject of fabric structure. Although the textural matter has been kept down to a minimum it contains all the "meat," and both the designs and the cross-sections through those fabrics which are included have been very well produced. W.H.S.

Der Flachs. Zweite Abteilung Flachsspinnerei. Technologie der Textilfasern Series, V.1. By W. Sprenger. Published by Julius Springer, Berlin, 1931. (254 pp. and Index, R.M. 38.)

This is one of the series published under the title "Technology of Textile Fibres," edited by Dr. R. O. Herzog. It is bound in the usual green cloth cover with gilt lettering, contains 256 pages with 175 illustrations, partly line drawings and partly photographs of machines, all of which are excellently reproduced. Throughout the volume much interesting data is given in tabular form, and at the end are four tables showing respectively—(1) Flax price variations since 1801. (2) Weight of bundles of different counts; equivalent counts in different systems; length and weight relations. (3) Older methods of bundling. (4) Power, floor space, and weight of the chief flax-spinning machines. The book is well indexed and the list of contents is set out very clearly in great detail. Aftor a historical introduction the subject is treated in sections, which follow the usual departments in a flax-spinning mill under the headings—raw flax; flax dressing for spinning; flax spinning; reeling, drying, and packing; attendance, administration, and maintenance of machines and adjustment; the layout of a flax-spinning mill; linen yarn; the mill organisation; flax-spinning calculations; flax yarn doubling. In the section on raw flax, the properties of the fibre are discussed, the methods of estimating quality by handling, and of marketing are described, and some remarks are made on the effect of humidity on the weight. The next three sections are purely descriptive of the machines used, including descriptions of hand hackling and hand spinning, and the purpose of the operation. All the machines for line and tow spinning are described in turn, the important motions of each being clearly illustrated by line drawings. Every opportunity is taken to achieve conciseness by the tabulation of data of dimensions of the machine parts, and by giving the calculations relating to the working of the machines in algebraical form. In this way the continuity in the description of the successive operations is maintained and not masked by pages of calculations as is so frequently the case in textile books. The descriptions of the machines include all the latest improvements such as automatic spreaders, recuperators on cards, electrical driving of spindles, various types of spindles, and automatic doffing. The section on carding is very complete, including tow refining and shaking machines, the finisher card, card waste shaker, short tow card, and cord-teasing machine. The section on spinning includes descriptions of the machines used for gill, dry, and wet spinning. The latter receives the most attention and discusses the methods of heating the water, the choice of temperature, the fluting of the rollers, and the length of the reach to be employed for different kinds of flax. Various methods of yarn drying are mentioned and brief descriptions given of several types of modern tunnel dryers. The section on attendance and administration describes the work in each department, and gives details as to the usual number and duration of stoppages for cleaning, the number of spindles per spinner, oiling, and so on. This section should be very useful to students and the information given is made more accessible by being grouped together in this way. The second part of this section deals with maintenance and setting of the machines, and reference is made to

auxiliary machines used such as roller fluting machines, pinning machine for card clothing, drilling machines. A section is devoted to buildings, motive power, ventilation, mechanical transport systems, weighing, fire protection, and accident prevention. The properties of linen yarns are discussed and methods of testing are described in ten pages. The subsection on testing machines might well have been amplified by including illustrations of the testing apparatus described, which would have been of assistance to elementary students. Actually only the Dietz yarn-testing machine is so illustrated. The author has introduced a further novelty in the make-up of this type of book, in a section entitled "The Spinning Organisation," which discusses in some detail how to estimate the numbers of each kind of machine required, having regard to the relation of the amount of tow to line machinery, the speeds of the machines, the draftings and doublings, and so on. Costing is dealt with briefly in four pages, and the last section describes some types of machines used in thread twisting, polishing, and softening. The author has been very successful in giving a very detailed account of all the processes of flax spinning, and the treatment adopted is to be commended for its clearness and conciseness. The book can be recommended as a valuable contribution to the subject and one which should be of considerable value to the technical student. At the same time it might be pointed out that the price of 38 marks (or at the present time over 45s.) appears to be unduly high for a volume of this size. J.A.M.

The Chemistry of Laundry Materials. By D. N. Jackman. Published by Longman's, Green & Co., 1931. (234 pp., price 6s.)

This little book has been written for laundry workers "in order to meet the demand which has arisen . . . for information about the materials encountered—particularly information of a chemical character." The chapters deal with water, alkalis, soaps, bleaches and stain removing, fibres and fabrics, starches, acids and blues, fuel, miscellaneous matter such as marking inks, fireproofing, mothproofing and simple analytical methods, the *p*H system, and lastly two chapters on general chemistry. The term "58° alkali" (introduced on page 11, but not explained till page 40) will, it is to be hoped, be dropped in favour of the simpler name "soda ash," which explains its nature more scientifically. An understanding of the *p*H system and its importance is well-nigh indispensable in modern applied science, and its explanation in simple language in this book is particularly good. Progress is made possible by accurate measurement, and the dissemination of scientific knowledge amongst the actual workers is a laudable object. The whole book is well written and does give the minimum scientific information which every laundry worker should aim at possessing. An excellent feature of the work is a considerable bibliography of books and papers for further study, including the references to the B.L.R.A. Reports at the end of each chapter. Laundry executives would do well to give a copy of the work to each operative—with his yearly bonus—and keep a copy for themselves. F.C.W.

The Cotton Trade and Industrial Lancashire, 1600-1780. By A. P. Wadsworth and Julia de Lacy Mann. Published by the Manchester University Press. (Pp. 539, price 25s. net.)

Everyone who knew the late Professor George Unwin will appreciate the gracious tribute by the authors of this work to "his immense range of knowledge and synthetic grasp." He had also the gift of inspiring others to share his enthusiasm for research, and Miss Mann and Mr. Wadsworth are unduly modest when they describe their book as "a poor contribution" to the wider scheme of industrial and social research which Unwin planned. Mr. Wadsworth began his studies with a view to presenting an account of the organisation and social background of the Lancashire textile industries in the period prior to the industrial revolution. Miss Mann, under the guidance of the late Professor Lilian Knowles, set out to trace the interaction between English and Continental developments. This initial independence has inevitably led to a measure of overlapping, and explains the "loose framework" within which the joint studies have been placed. But the thoroughness with which both authors have explored new and valuable sources of information in the Public Record Office, in the French *Archives Nationales*, in the private papers of such firms as J. & N. Philips, in legal and political records, is adequate compensation for the enforced lack of continuity in the story they

tell. A work of this type is most valuable because it helps to correct the impression so firmly stamped on many minds that all the essential features of modern industrial structure and working date from the industrial revolution. In the seventeenth century "credit was almost as indispensable to the textile industries as it is to-day," and an elaborate mechanism of trading was built up long before the banks as we know them were established to specialise on the function of finance. In fact it was not until after 1770 that either Manchester or Liverpool had a formal bank.

We are reminded also that in the seventeenth century "agrarian politics came home as closely to the Lancashire cloth producer as the affairs of industry," and it is interesting to trace the process by which problems of tenure, rights of grazing, and the use of the waste were transformed into questions of rates of pay and conditions of work as mechanisation of production displaced the "yeoman" type. Those who think of workers' organisations solely in terms of the nineteenth century history of trade unionism will appreciate the account here given of local associations in the eighteenth century preoccupied with the problem of the price of foodstuffs, and driven from secret to open action in years of acute distress and general social disturbance. Nor is the capitalist employer the peculiar product of the nineteenth century, for in the eighteenth century "considerable sections of the workers in Lancashire were dependent on a few men." It was not, however, until the nineteenth century that Lancashire established her supremacy in the world's cotton trade. It is particularly instructive to read of the "commission system" in its various phases, because this practice has come right into our modern factory system in full measure, though few, probably, will realise the length of its history.

Other instances might be quoted of features of modern textile practice dating back to the sixteenth and seventeenth centuries, but some reference must be made to other items in this fascinating book. Take, for example, the story of the workers' opposition to the Dutch loom (a "devilish invention"); the concern of English manufacturers when the old Kendal green and the rough friezes became drugs in the market because people's tastes ran to "foreign fashions and inventions"; the increase of the scale of manufacture as the market for textiles extended; the controversy about the "middleman" (so modern in its arguments); and the jealous defence of craft and trading rights in the contest between "town" and "country" producers. Need further quotations be given to show that although the main problems of industry and trade have changed in scale in the course of the last four hundred years, we still struggle with fashion, foreign competition, "middleman" dealing, industrial regulation, and the dislike of "rationalisation."

The textile technologist will turn to this book with pleasure, for he may read of fustians, bays, kersays, minikins, and the rest, and reflect upon the place occupied by the manufacture of velvet in the development of Lancashire's staple industry. The discovery of some early seventeenth century cotton cloth and cops at Hackling Hall is recorded, and the story of the displacement of wool working in Lancashire may be linked with the suggestion that water supplies were really more important than climate in determining the localisation of the cotton industry. Lancashire people who know the villages of the county will find much delight in reconstructing the activity and prestige of many centres since reduced by the modern industrial town to insignificance. Those with a taste for the study of "industrial relations" will find that an eighteenth century dispute between employers and operatives lacked nothing in invective, and in days when we hear so much about standards of living it seems quaint to read that the increase of tea-drinking between 1720 and 1750 was a sign of an "advance in real wages."

Such an admirable piece of historical research is bound to inspire others to take a hand in unfolding the whole story of textile developments. For the technician it is also sure to yield a new pride in his craft. A.N.S.

Mitteilungen der Textilforschungs-Anstalt, Krefeld.

Those engaged in research on rayon and interested in methods of testing will know that some of the most noteworthy contributions to these subjects emanate from the laboratories of Dr. W. Weltzien at the Textile Research Institute, Krefeld. These reports appear in the monthly journal, *Seide*, which is now in its 36th year, but they are also collected together in separate annual volumes of "Mitteilungen." The Institute acknowledges with satisfaction the donation of Volumes II–VI. W.

Sur la fixation des Matières grasses émulsionnées par les fibres textiles. By Jacques Corbière. Published by Soc. Anon. de l'Impr., A. Rey, Lyon, 1931. (121 pp.)

The absorption by textile fibres of oils and fats from emulsions is a problem of no little importance to the textile industry throughout the whole series of treatments which textiles undergo from the raw to the finished state, and it is a problem which is still in need of a comprehensive treatment. This book describes the results of some work carried out on the absorption of olive oil by wool and of linseed oil by viscose from emulsions of these oils. The first part of the book is devoted to a general discussion of emulsions and their application to the textile industry. The second part deals with the application of emulsions of olive oil to wool, particularly for carding and spinning purposes, and the influence of various factors such as particle size, soap content of the emulsion, and *p*H of the wool on the absorption of the oil is discussed with reference to the experimental results obtained. The remaining half of the book—some 50 pages or so—is devoted to a consideration of the drying of linseed oil in general, and the effects of various factors such as the degree of oxidation of the oil, concentration, and soap content of the emulsion on the amount of oil absorbed by viscose, are discussed from the point of view of the use of linseed-oil emulsions in the sizing of viscose. Consideration is also given to the effect of the ageing of linseed oil on the yarn. Some 100 fairly general references are included in the text. From the title it would be gathered that the absorption of oils from emulsions is dealt with in relation to textile fibres generally, but actually the treatment given is rather too confined to make the work of any very general interest. It is to be hoped, however, that it may pave the way to a wider and more comprehensive treatment of the whole problem. D.A.D.-S.

Silk and the Silk Industry. By Joseph Schober, translated by R. Cuthill, M.Sc., Ph.D. Published by Constable & Co. Ltd., London, 1930. (21s. net.)

This book by the Director of the Hungarian State Filatures, the German original of which was first issued a few years ago, presents surveys of the silk industry, and of the artificial industry considered in its relation to it, from the commercial and statistical as well as from the technical standpoint; the chemical and physical properties of silk are not discussed in detail. The text has been rewritten in part and extended by the author for this translation, and the translator has added sections on the British silk industry. The technical methods, geographical distribution, and trade statistics and usages of each section of the industry are considered together, those of each section in a separate chapter, which is thus in a manner self-contained. Thus Chapter I, on the Cocoon, after introductory sections on the history of the industry and more particularly of the British industry, gives a short account of the principles of silkworm rearing, an informative description fully illustrated of the various kinds and grades of cocoons, a short description of the properties of silk, and a much more detailed discussion of silk cultivation as an industry throughout the world. Japan is the leading sericultural country; its annual crop of cocoons has risen from about 8 million kg. in 1870 to about 370 million kg. at the present time; and in the export of silk it has far outstripped China where, however, the internal consumption is of an enormous but unknown amount. India, in which sericulture is on the whole unorganised, has lost her former position of importance as a silk-producing country. Italy maintains her position as the greatest silk-producing country in Europe and, although her output is small compared with that of China and Japan, she retains her supremacy in the art of sericulture. France, Greece, Bulgaria, Turkey, and other European countries produce much smaller, but (except in France) now increasing, amounts of silk. The Russian crop of about 17 million kg. of cocoons annually now exceeds the pre-war figure. In the British Empire the development of sericulture, which has had a notable success in Cyprus, is fostered by the Advisory Committee on Silk Production of the Imperial Institute. The world's output of silk, or rather perhaps the amount marketed, is now nearly double what it was just before the war. Japanese and Chinese silks, which constitute the greater part of the world's output, are marketed already reeled, or reeled and thrown, but there is a cocoon trade at Milan the usages of which are described. The next five chapters on Silk Yarns, Artificial Silk, Weaving, Ribbons, Knitted Goods, give each in the same way the geographical distribution, statistics, and trade usages of the section of the industry concerned, a plan which, whilst it

involves some repetitions, is successfully executed. In the well-illustrated technological parts of these chapters the descriptions of the mechanical processes of manufacture, particularly weaving, are more complete than those of the chemical processes which, however, apart from some minor errors, are quite sufficient for the scale of the book. There is a final chapter on Cloth Analysis. This useful book contains also a bibliography, glossaries of technical terms, and a list of equivalent technical terms in English and other languages. S.

Artificial Silks. By S. R. Trotman, M.A., F.I.C., and E. R. Trotman, Ph.D., M.Sc., A.I.C. Published by Griffin & Co., London (pp. 274+ix with 79 illustrations. 18s. net).

The authors, after a short introduction, have devoted about 140 pages to the methods of manufacture of various kinds of rayon, 20 pages to analysis and testing, and the rest to bleaching, dyeing, and finishing. The introduction is, frankly, disappointing; the description of manufacturing methods may be accurate but it is not easy reading, and the latter portion of the book is but good in parts.

It is perhaps unfair to criticise portions of a book away from their context, but in order to illustrate the non-critical way in which this book has been compiled, it may suffice to examine the authors' views on the subject of the moisture relations of cellulose in general, and of artificial silk in particular. On page 9 they write that ". . . . cellulose . . . . exposed to a damp atmosphere . . . . absorbs 18% of water." On page 190—"the moisture content (of artificial fibres) is usually between 10% and 12%," and on page 195 appears the really extraordinary statement that "yarn is bought and sold on the understanding that the sum of the dry weight and 11% of the dry weight shall be exactly 100." There is little about moisture equilibrium, nothing about absorption hysteresis, no hint that the magnitude of the moisture regain is connected with the chemical reactivity of the cellulose, and no emphatic statement about the different behaviour towards moisture of regenerated cellulose and ester rayons.

There is need for an authoritative book on rayon, but, unfortunately, as the authors of this book afford little evidence of first-hand experience of the material they set out to write about, and recent work seems to have been rather overlooked, it is hardly possible to commend this book as meeting the need. H.H.

PUBLICATIONS RECEIVED AND PLACED IN THE INSTITUTE LIBRARY

Kingston's Dollar Equivalent Tables. Published by Kingston's Translations Institute, Leadenhall Street, London, E.C.3.

The Tables cover exchanges of 1/16d. to £100 at eighteen rates of exchange.

The Lancashire Textile Industry 1931, and

The Yorkshire Textile Industry 1931-1932 (Worrall's Standard Textile Publications). Published by John Worrall Ltd., Oldham (16/- each).

These two volumes have been revised and brought up to date. Each has been made more comprehensive to justify the change of title, and improvements in appearance have certainly been effected.

Cotton Production and Distribution in the Gulf South West. U.S. Department of Commerce, Washington, 1931.

The volume is one of a series compiled in connection with a commercial survey of the seven States embraced in this area—Arkansas, Louisiana, Mississippi, Missouri, Oklahoma, Tennessee, and Texas.

Report of the Committee on Finance and Industry. (*Chairman*—The Rt. Hon. H. P. Macmillan, K.C.). Printed and published by His Majesty's Stationery Office. Price 5s. net.

THE

Journal of the Textile Institute

VOL. XXII—1931

PROCEEDINGS—NAME INDEX

In this Index (C) indicates that the matter is the subject of a Communication, and (R) that the matter is a Review.

PROCEEDINGS—SUBJECT INDEX

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THE JOURNAL
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VOL. XXII—1931

TRANSACTIONS AND INDEX

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THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

1—ROLLER DRAFTING IN THE WORSTED INDUSTRY

By A. C. GOODINGS, Ph.D.
(Department of Textile Industries, Leeds University)

INTRODUCTION

The great variety to be found in wools from the different breeds of sheep extant, necessarily implies selection of wool for manufacture in accordance with its ultimate use. Worsted yarns are to-day manufactured from almost every type of wool and, as a consequence, a large variety of such yarns exist. Every yarn is particularly adapted for the production of some special product; for example, coarse mountain wools are suitable for carpets, and fine botany wools for the best quality suitings and dress goods, and the interchange of these wools for the purposes mentioned would be impossible.

The variations from one wool to another include such physical factors as length, average cross-sectional area, crimp, elasticity, etc.; even in the same type of wool a marked divergence of certain properties is evident. Perhaps the most noticeable in this respect is that of length, accentuated from the original state in the fleece by breakage. Some attempt to approximate to uniformity is made prior to processing, by "sorting," and in worsted yarn manufacture the very short fibres are removed in the combing operation.

The most important qualities possessed by a good worsted yarn are uniformity of diameter or "levelness," and strength. A yarn may be level and lack strength or may be strong and not uniform, but unevenness in diameter usually results in weakness at the thin places. Thus, in general, an irregular yarn lacks both of the most valuable attributes of a well-spun thread, and a minimisation of these faults is a primary aim throughout the whole of the worsted processing operations.

The system, on which all worsted spinning processes are based, consists of the use of two pairs of rollers, one pair of which is made to run at a faster surface speed than the other. The wool slubbing in its passage between them, is gripped by each pair of rollers in turn, and the faster surface speed of the latter pair results in the attenuation of the sliver. Some means of control of the fibres between these two pairs of rollers is necessary, and it is in this that the English and Continental systems differ. While the Continental method makes use of pin control in the form of porcupines, the Bradford system depends upon the use of twist inserted during the previous operation, together with the aid of carrier rollers. The latter refers of course to those operations subsequent to the spindle gill box. The method of twist and carrier control is used in both English open and cone drawing, the latter only differing from the former in the positively driven bobbin on which the material is being wound and affecting for any one operation only the twisting and winding on of the material.

Practical experience has largely determined methods of manipulation of wool in order to obtain the best results. Limitations have been laid down with regard to the amount of draft that can be safely applied at any one

drawing operation under the present system of working, variable according to the type of wool. The necessity of "doubling" for the sake of levelness was early realised. The amount of twist to insert in any particular slubbing, the setting of the ratch and carrier rollers, are practical points which require the closest attention to detail if a good uniform yarn is to result from the final spinning operation. Such settings, etc., must be made to suit the requirements of the particular wool being processed, and no hard and fast rules can be laid down concerning them.

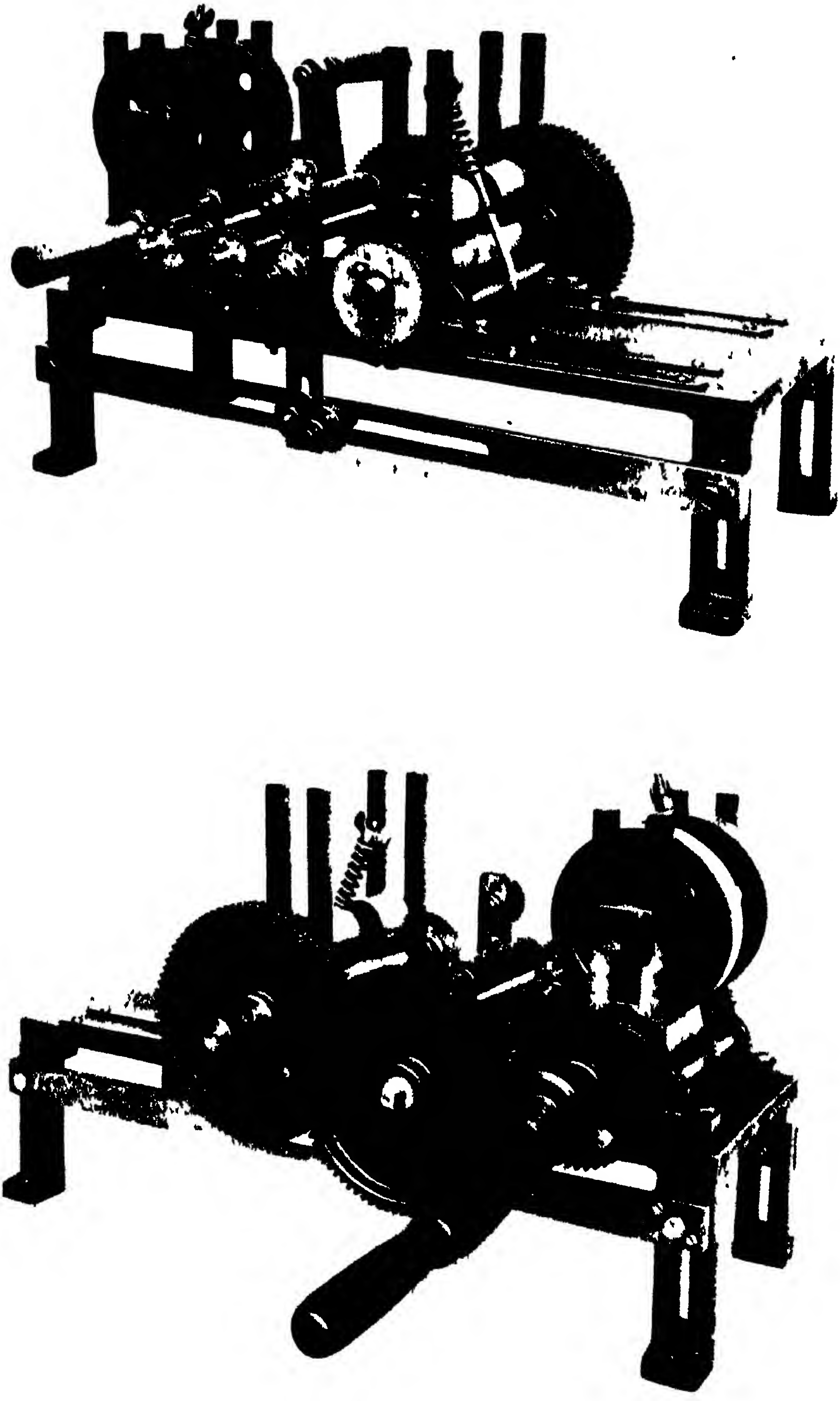
While absolute uniformity in a yarn is desirable, it remains only an ideal to which the results of practice approximate to a greater or less degree. No yarn is perfect in respect of levelness, while some are extremely bad: the diameter of the thickest portions varying to more than twice the diameter of the thinnest portions. Further insight into the causes of such irregularities and the way in which wool fibres react to the present mechanical system of drafting, is a first essential to success in any attempt towards the production of a better yarn. The following investigation was undertaken with this aim in view. Discussions between Professor A. F Barker and the writer, on fibre movement and roller drafting in general, formed the starting point of the work. For the sake of clarity the results obtained are sub-divided under two headings—(1) Irregularities in slubbing and yarns due to the drafting operation; (2) fibre movement in drafting.

IRREGULARITIES IN SLUBBINGS AND YARNS DUE TO THE DRAFTING OPERATION

Many mechanical defects, such as nicked or bellassed rollers, loose bosses, etc., are well known as giving rise to irregularities in slubbings and yarns. Such defects, however, are more or less easily traceable to the machine causing them and their appearance carefully watched for by the drawing or spinning overlooker. Despite freedom from all such mechanical faults, it is still impossible to produce a perfectly level slubbing. This fact is clearly shown if an attempt is made to reduce down a sliver without doubling. The necessity for doubling at every operation in worsted processing, except, in general, in the final spinning, irrespective of how well the wool has previously been gilled, in itself suggests some inherent defect of the roller system of drafting.

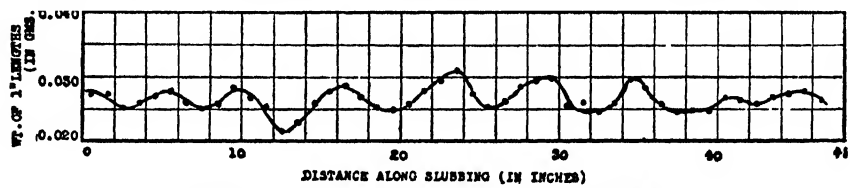
In order to gain some insight into the magnitude and occurrence of irregularities in slubbings and yarns during the various drafting operations involved in the drawing and spinning of a wool, an examination was made of the slubbings, roving, and yarn at every box in the manufacture of a worsted yarn from a 64's Botany wool. After combing, the wool was well gilled with consequent doubling, to ensure as far as possible an even fibre distribution in the sliver prior to drawing. The drawing itself was carried out according to ordinary mill practice, the drafts, doublings, and other settings being such as to suit the wool used. The operations subsequent to the finisher gill box consisted of two can gill boxes, spindle gill, six drawing operations, followed by cap spinning.

The method of analysis employed in determining the uniformity of the various slubbings and yarn was a weighing method. The portion to be analysed was cut into short equal lengths, and these weighed separately on a chemical balance. Results were then represented graphically, weight per unit-length-taken being plotted against position on the slubbing. A convenient unit of length in the case of a 64's Botany wool was found to be 1 in.

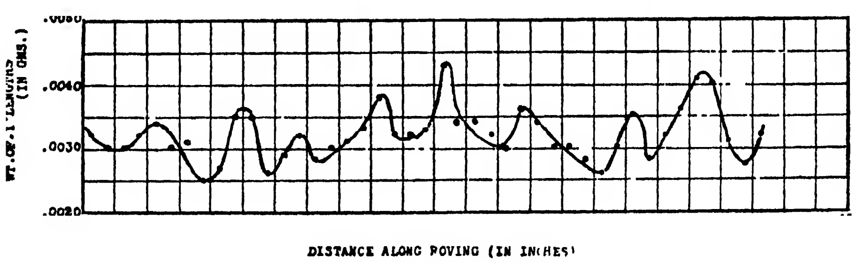


Two views of the Drafting Mechanism employed

The plotting of the linear measure in English units has an additional value in that it is generally used in the expression of length of ratch, amount of twist, and other allied measurements in this country. Further, in dealing with "fibro" (cut artificial silk), experiments involving the use of which will be described later, the material supplied by the manufacturers is cut into lengths most easily expressed by using an inch as the unit. These are 6 in. and 4 in. for admixture in the wool trade, and $1\frac{3}{4}$ in. for blending with cotton. Owing to the large amount of time and labour involved in the method of analysis outlined above it was only found possible to obtain data for comparatively short lengths of slubbings and yarns, but in cases where it was deemed necessary, longer lengths were examined. Portions selected at various intervals gave, however, similar results and showed the irregularities which it was desired to observe over comparatively short lengths. It was deemed advisable, also, to retain the weight method of analysis as giving an unequivocal measure of the variation of the bulk of fibres present from place to place along the portion analysed. The results obtained at the various stages in the processing of the Botany wool showed the same type of irregularity in each case. Graphs I and II show the results obtained for the slubbing and roving from the finisher box and rover respectively.



GRAPH I. Botany Slubbing from Finisher Box.

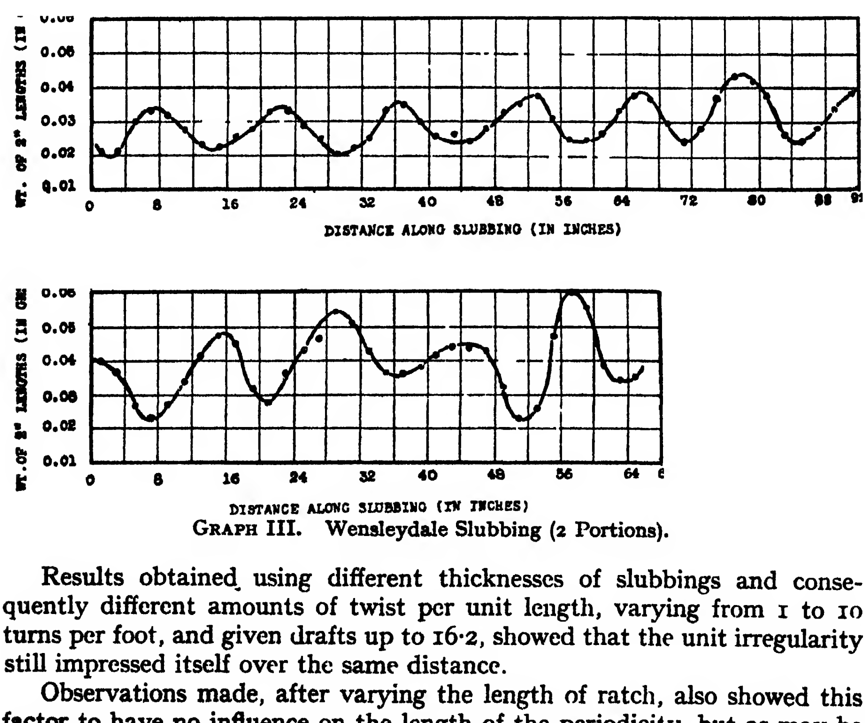


GRAPH II. Botany Roving from Roving Frame.

The analysis of the yarn was done by a different method, the instrument used being devised by W. T. Astbury, to whom I am indebted for these results. The method consists essentially in the change of resistance in a short column of mercury down the centre of which the yarn, under pressure, is made to run. The resistance readings can be converted to cross-sectional areas which was done in this case. A comparison of the results obtained by the two methods showed that the same type of irregularity existed in the yarn as found in the preceding slubbings. Perfunctory examination of the results at once revealed *maxima* and *minima* occurring at fairly close intervals. Further examination showed the variations to be in the nature of a wave form, fairly constant in wave length. The amplitude, however, varied considerably, or, in other words, the magnitude of the thick or of the thin places was far from constant. This amplitude variation showed an increase at each operation and reached a maximum in the yarn. The distance between

two consecutive *maxima* or *mimina* appeared approximately to be the same irrespective of the operation. This latter observation implies that irregularities set up are of such a nature that the distance between two consecutive thick or thin places is the same for different drafts, at any rate within the limits of those used. Other factors varying from one drawing operation to the next are, of course, the amount of twist, the weight per constant-length of slubbing, and actual speed of the machine as distinct from the speed ratio which determines the draft. The constancy of the wave length of the irregularities set up tends to the conclusion that the distance between successive *maxima* or *minima* is independent of the machine and its adjustments and is dependent only upon the type of wool itself. This approximately equal spacing of the irregularities shows some order in what might otherwise be regarded as a purely haphazard effect.

In order to investigate further whether the wave-length is uninfluenced by the draft and also the effect of the latter on the amplitude of the variations, the same Botany slubbing was taken and three widely varying drafts were successively applied. These were calculated drafts of 7·8, 11·1, and 16·2. Further, in these and the cases which follow, the drafting was done on a single end. The analysis of the slubbings produced was carried out as before by the cutting and weighing of short lengths. The results showed that the amplitude, or extent, of the irregularity increases with increase in the draft at the same time becoming more regular in wave form. The distance between two consecutive *maxima* or *minima* remained the same, however, in all three cases and equal in value to that previously found in the complete drawing process.



Graph III. Wensleydale Slubbing (2 Portions).

Results obtained using different thicknesses of slubbings and consequently different amounts of twist per unit length, varying from 1 to 10 turns per foot, and given drafts up to 16·2, showed that the unit irregularity still impressed itself over the same distance.

Observations made, after varying the length of ratch, also showed this factor to have no influence on the length of the periodicity, but as may be

expected the variation between thick and thin places became more pronounced as the ratch was increased.

Other types of wool studied in a similar manner each showed a more or less regular recurrence of ***maxima*** and ***minima***, but the distance at which they were interspaced varied from one wool to another. Graph III shows the results obtained on a Wensleydale wool with a draft of 25. As was noticed in the case of drafted Botany slubbings, the difference between thick and thin places becomes more pronounced with the higher drafts, but the deviation from uniformity more regular in wave character. In examining other wools for the length of the wave period, advantage was taken of this fact, and high drafts were applied in order to facilitate measurement. The wave-length for Wensleydale will be seen to be extended over a distance of 14 inches, and in order to minimise the labour involved in weighing, two inches was used as the unit instead of one as in the case of Botany.

Experiments involving varying drafts and other conditions on slubbings of Kerry Hill wool, Romney Marsh, and a 46's crossbred, gave similar results to those obtained in the case of Botany and Wensleydale. Table A summarises the various wools and the average distance between two successive thick and thin places produced in the drafting operation. The length analyses of these wools are given in the Appendix.

Table A

Type of Wool	Wave length	Mean length
64's Botany	5 in.	2·4 in.
Romney Marsh	6	3·2
Kerry Hill	6½–7	3·8
46's Crossbred	8	3·6
Wensleydale	14	6·4

Observations have previously been made by Balls in connection with cotton spinning ("Studies of Quality in Cotton"), in which he noticed the occurrence of ***maxima*** and ***minima*** more or less equally spaced and irrespective of the operation or the draft applied. He states the existence of "a regular recurrence of thicker or thinner places as if the drafting had made it irregular to a slight extent but in an orderly manner . . . . In all three machines the length of the newly generated waves would appear to be at least broadly similar." He further points out the existence of a secondary wave due to the drawing out of the irregularity set up in the previous operation. A measurement taken of the length of this secondary wave enables an evaluation to be made of the draft applied at the preceding drawing. It should be noted, however, that this applies to the drafting of a single end. Any doubling would of course interfere by the neutralising effect of one end on another.

In the case of wool drafting, where two or more ends are run together, the primary wave in each slubbing is attenuated in proportion to the draft making what are referred to later as secondary waves, and fresh primary waves set up. The total effect in the slubbing, resulting from this operation, is a combination of the additive effect of the secondary waves together with the newly created primary or primaries, the latter depending upon whether each end acts as an individual in the creation of an irregularity or whether they act in unison. Experiment and general practice show that the latter supposition is not true. The more ends put up at the back of a drawing-box, the more level is the resulting drafted slubbing. Were all ends to act as one in the

creation of a primary wave, this would not be the case to such a marked extent, for the only levelling factor would be that of the more complete elimination by combination of secondary waves. The variation between thick and thin places expressed as a percentage of the mean weight value in the case of slubbings of a Botany wool gave values of the following order—

Drafting of a single end	... ...	40% and over.
„ 2 ends up	... ...	20–30%
„ 3 ends up	... ...	10–15%

The amplitude of the wave is decreased with increasing number of ends, and consequently it must be concluded that each acts as an individual. The irregularities in a slubbing where several ends have been run together are the compounded effect of a number of approximately equal primary waves, together with the secondary waves of each constituent slubbing. The amplitude of the combination of the various secondary waves depends upon the relationship in which the existing primary waves of the individual slubbings come together. Moreover, as these primary waves are not exactly equal in wave length, and the tension on each slubbing is not always the same, the positional relationship must constantly alter. The total effect, therefore, of the component due to the drawing out of the existing primaries will be something varying in amplitude and having an ill-defined or no-wave character. The primary waves which are set up will for the same reason give variation in amplitude, but will be more gradual in their change owing to their approximately equal wave length, and the change of phase, slow enough not to interfere with the equal interspacing of the *maxima* and *minima*. The variations measured in the slubbing are therefore the superimposition of approximately equally spaced *maxima* and *minima*, but with variable amplitude on a smaller variation of ill-defined or indefinite character. The resultant of these two is such that the wave length is more or less preserved but the amplitude variable. In the case of high drafts, the secondary effect is practically negligible. The drafting of a single end with a high draft should therefore give a wave more regular in character. This fact has previously been mentioned as having been found to be the case in experimental work. Measurements taken on long lengths of slubbings where doubling had been resorted to, did not show any secondary wave, at any rate where more than two ends had been run together, and in this latter case its existence was doubtful. In the case of yarn, however, spun from a single end, such secondary wave could be discerned.

The effect of drafting twice in the same direction, as compared with the normal procedure of drafting from the opposite end, showed an increased irregularity in the former. This points to the fact that the drafting operation upsets the equal distribution of the fibres. The value of drafting from the opposite end at each operation lies in the unequal fibre lengths present in the wool.

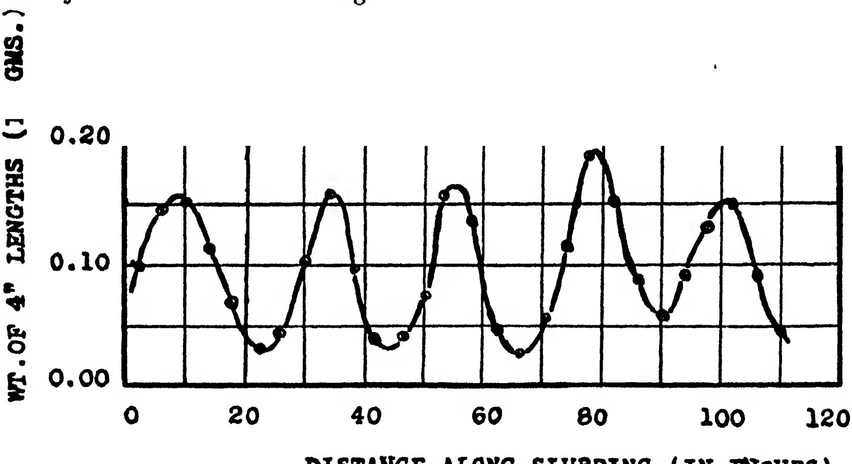
That the cause of such irregularities may be due to the great variation in the lengths of the constituent fibres of the wool with consequent decrease in control of the shorter fibres, is conceivable. For the elucidation of this point use was made of "fibro." This cut artificial silk is composed of fibres all of the same length. In drafting it was found necessary to ratch at least one inch over the fibre length, otherwise binding took place and the slubbing would not draft out. Experiments carried out with 4 in. and 6 in. fibres gave results similar to those of wool but with a considerably increased wave

length. The amplitude variations were of the same order as in the case of wool, but the variations were more regular in form. The wave length, however, as in the case of wool, did not appear to vary with the draft. Graph IV shows an extremely regular periodicity obtained on a slubbing composed of 6 in. fibres given a draft of 4 on a single end. The irregularities in the slubbings composed of 6 in. fibres were more pronounced and more uniform in character than in the case of 4 in. fibres. A slubbing composed of 3 in. fibres was prepared, and another of 2 in. fibres. Table B gives the average wave length of the irregularities produced and the length of the fibres composing the slubbing.

Table B

Fibre length	Wave length
6 in.	20-24
4 ,,	15–16
3 ,,	10–12
2 ,,	7– 8½

It will be noticed that the average wave length for this "fibro" is approximately four times the fibre length.



GRAPH IV. 4" Fibro Slubbing.

The effect of low drafts was studied both on wool and "fibro." The average wave-length of the irregularity produced did not deviate much from what had been found with higher drafts. The results showed a slightly higher value in the case of wool and a somewhat lower value in the case of artificial silk. Drafts of 1½, 2, 2½, and 3 were applied in the case of wool, and in the case of a draft of two a very pronounced fall was experienced after every second primary wave. This was due to the secondary and primary waves reinforcing one another in the minimum position. As a whole the irregularities in the case of short drafts do not take such a definite form and the amplitude variations are of much less orderly character, a result to be expected from the increased importance of the secondary waves.

FIBRE MOVEMENT IN DRAFTING

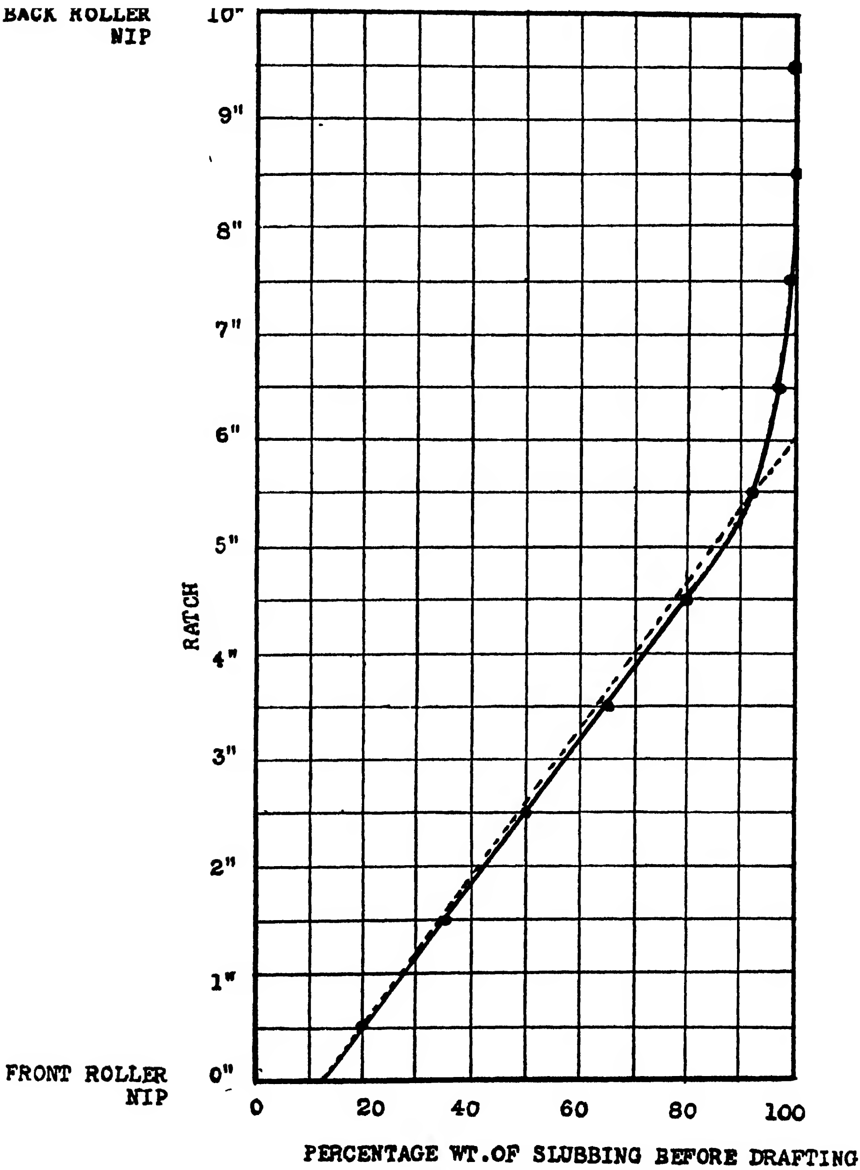
In order to avoid breakage of fibres during the drafting operation, it is necessary that the distance between the back and front rollers should be equal to, or slightly greater than the length of the longest fibres being manipulated. The result of this is that for a certain distance between the two

pairs of drafting rollers, all fibres except the very longest are uncontrolled by either pair of rollers and carried forward by virtue only of surface frictional contact with other fibres. The greater the variation in the uniformity of length of the various fibres, the greater the distance which the shorter fibres have to travel in the ratch controlled only by this latter means. A consideration of the manner in which such "free" fibres may move presents two possibilities. They may either move only at one of two speeds, the surface speed of the back or front rollers; or they may assume some intermediate and variable speed. Allowing of only two speeds they may be carried forward at higher speed as soon as leaving the nip of the back rollers, or not until entering the nip of the front rollers, or at some intermediate position dependent upon the length of the fibre. To elucidate which of these possibilities actually takes place in practice, the variation in weight of that portion of slubbing between the back and front rollers offered itself for investigation. It was necessary first of all, however, to determine the effect of actual speed on fibre movement in drafting. For this purpose an experimental machine was designed which could be brought to rest suddenly from normal running speed. Results obtained at different speeds did not show differences and agreed with those obtained making use of an ordinary drawing box. In this latter machine, after the driving belt has been put over on to the loose pulley, the machine gradually slows down and finally comes to rest. The above result is not surprising, for no extraordinary variations in the thickness of slubbings are to be found when a machine is started up or stopped. Frequent and more rapid starting and stopping on the small experimental machine confirmed this.

The decrease in weight of a slubbing from the back to the front rollers due to drafting was investigated by cutting this portion into short lengths and weighing these on a chemical balance.

In the earliest experiments several portions were so cut and corresponding portions weighed together and an average result for the weight diminution thus obtained. While such results are an average and mask any fluctuation which may have taken place from one to another, they do show the manner in which uncontrolled fibres move during drafting. Experiments carried out with cut artificial silk consisting of 6 in. fibres gave the weight diminution curve shown in Graph V. There is little diminution in weight of the slubbing until that distance behind the front roller nip equal to the fibre length. From this point the decrease in weight is unifrom down to the nip of the front rollers where the slubbing emerges without further alteration at an average thickness governed by the draft. Results obtained by varying the length of ratch, carrier positions, and draft, are all of the same type. Consideration of this weight variation shows that fibres move only at the surface speed of the back rollers until actually gripped in the nip of the front. Similar experiments carried out on wool showed identical results as regards the movement of fibres. In the case of wool, however, the analysis of the weight reduction graphs was complicated by the variation in the lengths of the wool fibres present. It was necessary to make a complete analysis of every wool used and construct weight-reduction curves assuming the results obtained with "fibro," i.e. movement at a slower speed of all fibres until actually entering the front nip. Curves so constructed for the drafts used agreed with the practical results obtained. Graph VI shows the results for a Botany wool and a theoretical curve based on the principle stated.

The third curve in Graph VI, giving a rapid diminution in weight near the back rollers, shows for comparison the theoretical curve representing weight reduction in the ratch during drafting for a slubbing of the Botany

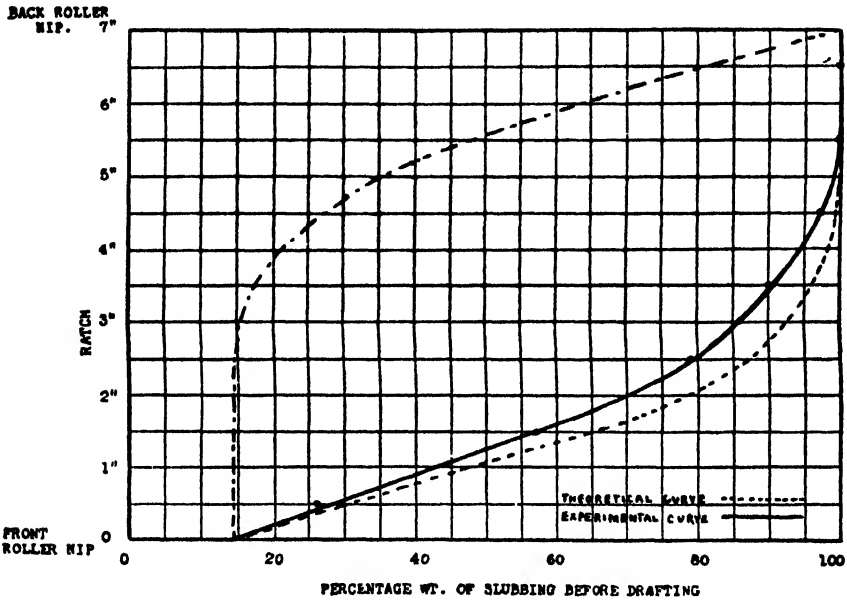


GRAPH V. 6″ Fibro Slubbing.

wool assuming all fibres moved at the surface speed of the front rollers as soon as released from the grip of the back rollers. This curve is constructed for a draft of 7 and ratch of 7 in.; the longer the ratch the further removed

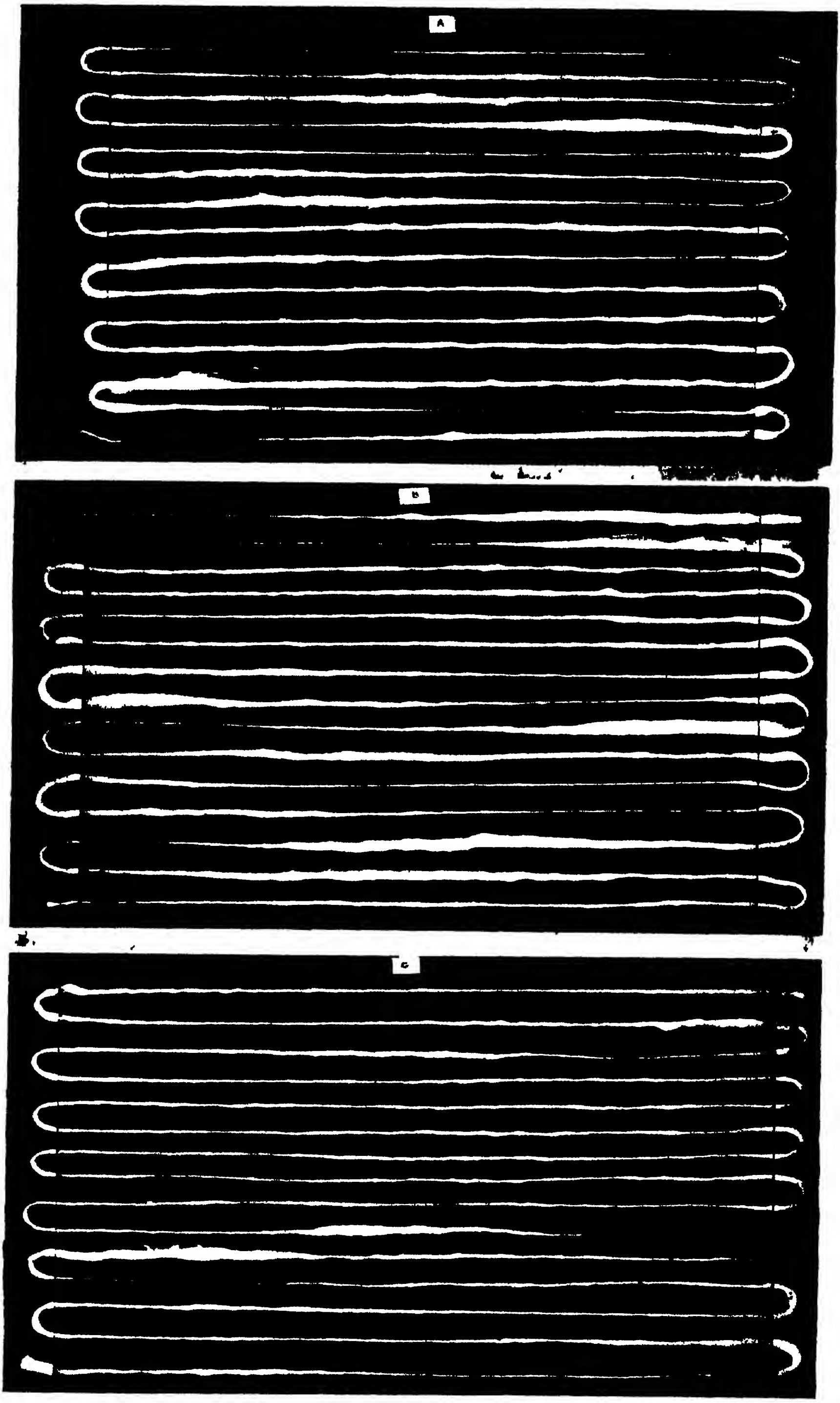
this curve would be from the theoretical curve based on the slow movement of fibres up to the front roller nip.

To determine more definitely variations in fibre movement, the reduction in weight in the ratch was obtained for single ends. While all results so obtained approximated to the average values previously found, variations from this were shown to occur. These variations are of interest in connection with the production of inequalities in the uniformity of slubbings and yarns.



GRAPH VI. Botany Wool (Draft 7).

Results obtained with "fibro," Botany, and Wensleydale wools were all of the same character. The point at which no further reduction in weight takes place varies from a position at the front roller nip to somewhere a short distance behind it. The results of numerous observations showed this distance to be greater in the case of a long wool than in that of a short wool, and very pronounced in the case of "fibro." While such individual observations render difficult an exact determination of the manner of such fluctuations, they do show their existence. Graph VII shows the case of a long wool where drafting is completed before reaching the front nip. In such cases fibres must have moved forward at the front roller speed before actually reaching these rollers, by virtue of contact with other fast moving fibres. In an attempt to correlate the production of a thick or thin place in a slubbing with these fluctuations, drafting was carried out under such conditions as rendered thickness variations visible to the eye. The change in weight was then measured on that portion in the ratch from back to front rollers for cases where thick and also thin places in the drafted slubbing were just emerging from the roller nip. The curves differed for these two cases, in the one there being no weight reduction in the slubbing for a short distance behind the front rollers, and in the other case reduction in weight proceeding right up to the nip.

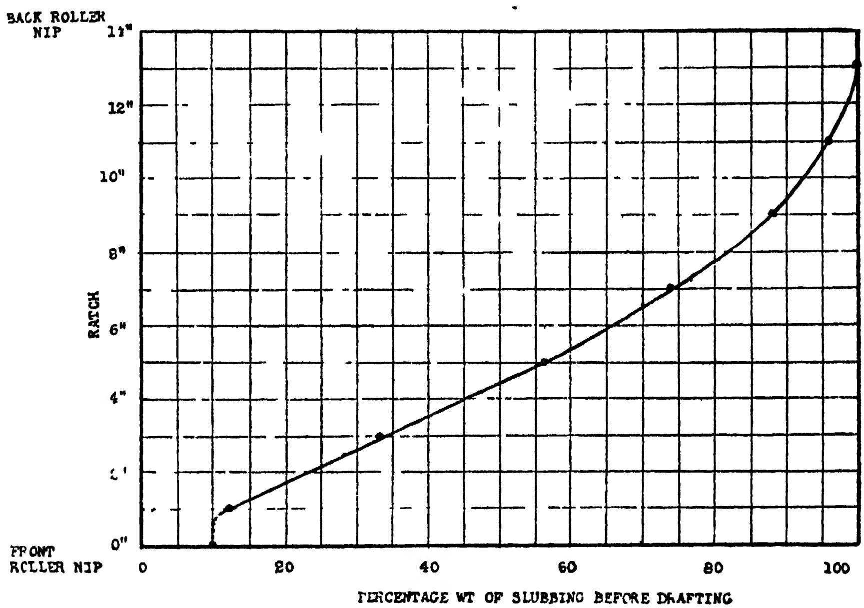


FIBRO SLIVERS

A. 6″ length (last draft 6).
B. 6″ ,, (,, 4).
C. 4″ ,, (,, 4).

Before attempting to discuss these results, some further observations on drafting may be worth mention. Under any ordinary conditions of setting, there is a limit to the amount of draft that can be applied in any one operation and still produce a continuous sliver. Beyond this maximum draft the wool is plucked away in tufts by the front roller, resulting in discontinuity. In such a case fibres which have not yet reached the nip of the front rollers are plucked forward and these are removed before those following behind at a slow speed enter the front roller nip, and discontinuity results. This maximum draft decreases with increasing length of ratch.

Attempts on a similar line were made with cut artificial silk, but at the highest draft which it was possible to apply, namely, 26 (limited by the mechanical construction of the machine), a continuous sliver still emerged from the front rollers.



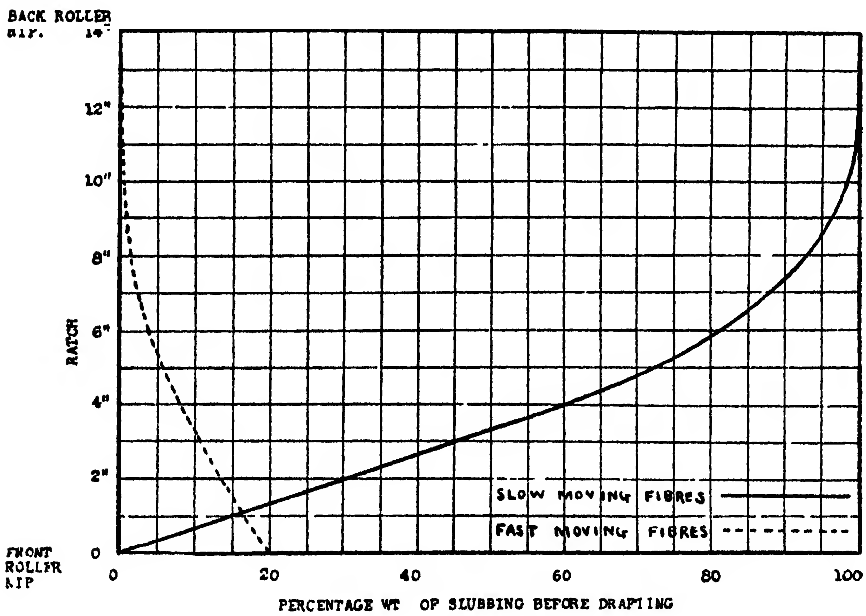
GRAPH VII. Wensleydale Wool.

The results on the movement of fibres in the ratch show that while all fibres approximate to slow speed movement until entering the nip of the front rollers, deviations from this do occur. Provided all fibres moved in the same manner it would be immaterial what this movement was. Consistency in movement would result in uniformity, but such fluctuations as have been shown to take place must affect the levelness of the material after drafting.

DISCUSSION OF RESULTS

It has been shown that in normal regular drafting, all fibres move at the surface speed of the back rollers until their foremost ends are taken into the front roller nip. They are then carried forward at the higher surface speed of the front rollers. Taking this as a basis for consideration, the relative

numbers of fast and slow moving fibres between the back and front rollers is instructive. In the case of a slubbing composed of uniform fibres, there is no reduction in weight until a distance behind the front roller nip equal to the fibre length. Reduction in weight of the slow-moving fibres takes place uniformly from this point down to zero weight at the front rollers. This is true irrespective of the draft applied. The weight component due to the fast-moving fibres gives a uniform increase from a point equal to the fibre length behind the front rollers to a weight equal to that of the initial slubbing divided by the draft at the front roller nip. In different drafts, therefore, the number of fast-moving fibres varies but the slow-moving fibres remain unaltered. The point behind the front rollers at which there are an equal number of fast and slow-moving fibres is equal to $l/d + 1$, where l equals fibre length and d equals draft.



GRAPH VIII. Wensleydale Wool (Draft 5).

In the case of a slubbing composed of fibres varying in length as in normal wool, the slow-moving fibre component is invariable while the fast-moving fibre component varies with the draft as before. The reduction and increase in weight respectively, however, is not uniform, and the point at which there are equal numbers of slow and fast fibres is equal to $l'/d + 1$, where l' is approximately the average length. Graph VIII shows for a Wensleydale wool the weight-reduction curves for fast- and slow-moving fibres under a draft of 5 The type of irregularity found in the case of slubbings of both wool and "fibro" is regular and in the nature of a progressive increase in weight up to a maximum followed by a gradual falling off to a minimum and a rise up to what is the average weight. A sudden plucking forward of any group of slow-moving fibres would not give this type of irregularity but

would give a rapid increase in weight over that distance wherein the front ends of the plucked fibres lay. The length over which an irregularity so caused would extend would be equal to $l + d.x$, where l equals fibre length, d equals draft, and x equals the distance over which plucking took place behind the front rollers. The weight-reduction curves obtained, on that portion of the slubbing in the ratch, as well as the type of irregularity produced, do not allow of this as an explanation. Moreover, as the wave length is approximately constant for all drafts the value $l + dx$ would have to equal a constant, or x must vary inversely as d. As the point at which equal numbers of fast- and slow-moving fibres is equal to $l/d + 1$ behind the front rollers, such variation would seem to be highly improbable. The results indicate rather a gradual building up process, followed by a falling off in the tendency of fibres to be plucked forward before reaching the front rollers.

It will be obvious from the graph showing relative numbers of fast- and slow-moving fibres that the controlling tendency is such that the retaining force is greater than the plucking force. On individual fibres, however, the plucking tendency may be the greater owing to their being in contact to a greater extent with the fast-moving fibres than is shown by distributed average force. The plucking forward of such fibres increases the number of fast-moving fibres and consequently creates a further tendency for plucking to take place. In this way a more gradual building up in thickness results.

For any irregularity which takes a wave formation by a gradual building-up process the minimum wave-length possible, where all the fibres are uniform, is twice the fibre length. It may be greater than this, but anything less would possess a uniform portion between the maximum and minimum values of the irregularity. The period of rise to a maximum must be affected by the surface friction between fibres, and this has been shown to be the case by experimenting on oiled and unoiled slivers of the same material. The oiled sliver produced a shorter wave-length as compared with the unoiled and more regular in uniformity of diameter. This may at first sight be paradoxical, but when it is considered that the force required to break an oiled sliver is greater than in the case where no oil has been applied, it will be realised that there is an increase in resistance to movement of fibre on fibre.

A more uniform wool approximating to a square top prepared by several combings still gave a wave-length of about twice the average length and therefore uniformity is not the factor causing the divergence between the wave-length compared to the fibre length of wool and cut artificial silk.

If surface friction is largely the determining factor, a fibre of some intermediate value as regards surface frictional properties should give an intermediate value in respect of wave-length. Cotton is probably one such fibre and irregularities in cotton slubbings on this argument should give a wave-length of between two and four times the fibre length. The value for cotton has not been determined in these experiments, and no precise published data are available.

An effect which must aid the faster moving fibres to carry others with them by means of surface friction is that unavoidably associated with the present roller system of drafting. At the front rollers the fibres are pressed close together in the nip, and hence the effect of surface friction at some distance prior to this point must be such as to aid the fibres in the majority. In other words, the fast-moving fibres have a greater tendency to pluck

other fibres with them owing to their more intimate contact with the slow-moving fibres due to the pressing together of the top and bottom front rollers.

The higher the draft the less the number of fibres in the ratch, and hence the less influence of one on another. With high drafts, therefore, the nip effect becomes more important, and hence the amplitude of the wave with such drafts will tend to reach greater dimensions. That high drafts do cause greater irregularities is well known. With longer wools the nip effect must become diminished in influence, and the use of higher drafts with longer wools more successful. This is in accordance with practice, although standard deviation in fibre length of such wools is greater than in the case of short wools.

For the same amplitude variation between thick and thin places, it is an advantage in many types of cloth to have the irregularity in wave-length extending over a shorter distance rather than a long. Where variations extend over a long length of yarn, the effect in a woven cloth is to give it a stripey appearance which cannot be rectified as long as that type of yarn is used. In the case where the fibres of the wool are very short, there is a tendency owing to the inadequacy of control to produce a very uneven yarn. It appears, therefore, that to produce a yarn which will eventually weave into a satisfactory cloth, that there is some intermediate value for fibre length from which the best results can be obtained.

The fact that every machine sets up and produces an inequality in the emerging slubbing, shows the inadvisability of producing a roving from a single end, there being no counteracting influence of one slubbing on another. The production of rovings in this manner has often been discussed, and in cases practised, but in the light of these results it is detrimental to the yarn produced from the final spinning operation. The advantage of spinning from a double end also follows from the same argument.

It is essential for the production of a level yarn that perfect fibre control in every operation be achieved. The Continental method of making use of pin control in the form of porcupines has advantages in this respect over the English draft against twist method. Neither, however, are perfect, and only an approximation to uniformity can be hoped for. A method by which all fibres are carried forward at the second and higher speed as soon as leaving the control of the back roller would eliminate the irregularising factor shown to be present in the system as used to-day, but the difficulties in the way of such a method have not as yet, at any rate, been overcome. To ensure control of every individual fibre, bound together, as they are, by the system of inserting twist, seems impossible; and so long as this method is adopted in worsted yarn production, it would seem that level yarns must remain an ideal to which the results of practice can only approximate.

APPENDIX

Analysis of Materials for Fibre Length

I—64's Botany Wool

Fibre length	% Weight	% No. of Fibres	Mean length
5 –5½ in.	2·3	1·5	
4½–5 ,,	6·6	3·5	
4 –4½ ,,	7·2	4·0	
3½–4 ,,	9·4	6·0	
3 –3½ ,,	15·5	11·6	2·4 in.
2½–3 ,,	12·5	11·0	
2 –2½ ,,	19·0	20·5	
1½–2 ,,	16·3	22·1	
1¼–1½ ,,	11·2	19·7	

II—Wensleydale Wool

Fibre length	% Weight	% No. of Fibres	Mean length
13–14 in	0·4	0·2	
12–13 ,,	2·6	1·3	
11–12 ,,	4·0	2·2	
10–11 ,,	7·2	4·4	
9–10 ,,	10·8	6·8	
8– 9 ,,	15·2	11·5	6·37 in.
7– 8 ,,	14·0	11·9	
6– 7 ,,	12·7	12·4	
5– 6 ,,	14·4	16·8	
4– 5 ,,	9·1	13·0	
3– 4 ,,	7·4	13·5	
2– 3 ,,	2·1	5·9	

III—Romney Marsh Wool

Fibre length	% Weight	% No. of Fibres	Mean length
5½–6 in.	5·0	2·7	
5 –5½ ,,	6·6	4·0	
4½–5 ,,	13·7	9·3	
4 –4½ ,,	19·3	14·7	
3½–4 ,,	11·1	9·5	3·22 in.
3 –3½ ,,	10·7	10·6	
2½–3 ,,	16·4	19·2	
2 –2½ ,,	9·3	13·3	
1½–2 ,,	4·85	8·9	
1 –1½ ,,	3·0	7·6	

IV—Kerry Hill Wool

Fibre length	% Weight	% No. of Fibres	Mean length
8 –8½ in.	1·5	0·7	
7½–8 ,,	1·5	0·8	
7 –7½ ,,	4·6	2·4	
6½–7 ,,	6·2	3·5	
6 –6½ ,,	8·05	5·0	
5½–6 ,,	8·3	5·5	
5 –5½ ,,	10·9	8·0	
4½–5 ,,	11·4	9·1	3·8 in.
4 –4½ ,,	11·95	10·8	
3½–4 ,,	9·6	9·8	
3 –3½ ,,	8·3	9·8	
2½–3 ,,	7·3	10·2	
2 –2½ ,,	4·5	7·7	
1½–2 ,,	2·8	6·1	
1 –1½ ,,	2·5	7·7	
½–1 ,,	0·6	3·0	

APPENDIX—*continued*

V—46's Crossbred Wool

Fibre length	% Weight	% No. of Fibres	Mean length
9–10 in.	0·55	0·2	3·55 in.
8– 9 ,,	3·5	1·5	
7– 8 ,,	6·0	2·8	
6– 7 ,,	10·4	5·7	
5– 6 ,,	17·0	10·9	
4– 5 ,,	17·0	13·3	
3– 4 ,,	21·8	22·1	
2– 3 ,,	14·45	20·5	
1– 2 ,,	8·7	20·5	
1 ,,	0·7	2·4	

VI—Artificial Silk (6-in. "Fibro")

Fibre length	% Weight	% No. of Fibres	Mean length
6½–7 in.	33·9	32·2	6·4 in.
6 –6½ ,,	66·1	67·8	

VII—Artificial Silk (4-in. "Fibro")

Fibre length	% Weight	% No. of Fibres	Mean length
5 –5½ in.	3·6	3·0	4·4 in
4½–5 ,,	27·6	25·7	
4 –4½ ,,	68·8	71·3	

2—STUDIES IN THE SAMPLING OF COTTON FOR THE DETERMINATION OF FIBRE-PROPERTIES

PART III—THE SIZE AND RELIABILITY OF A SATISFACTORY SAMPLE

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SUMMARY

The main object of this Part has been the assigning of the minimum number of tests which can be regarded as satisfactory for the determination of the following fibre-properties—length, width, convolutions, strength, and rigidity. The chief method employed has been the comparison of the mean values of small samples of various sizes with the mean value of a large sample, the latter usually comprising 3,000 individual test-values. In order to obtain a large number of samples of any given size, the "moving-mean method" has been used. By inspection of the frequency-distribution of the means of the samples of each size, the proportion of the means lying between any assigned limits has been ascertained, and thence the odds that any single mean of a sample of the given size will lie between these limits. The odds applicable to the same limits for the means of samples of the same size, normally distributed with a probable error of a single observation calculated from that of the whole bulk of the material, have also been given, in order that the experimentally ascertained odds might be compared with the purely theoretical normal odds. The results have also been investigated for each fibre-property by comparing the dispersion of values of small and large samples, and by comparing the actual frequency-distributions of small samples with the theoretical frequency-distribution of a large sample.

The following are the conclusions arrived at as a result of the present analysis—

(1) Although the method of sampling adopted must usually be decided from certain general considerations, we have been able to show that the method of selecting individal fibres from a carefully-prepared sliver in which the fibres have been thoroughly mixed, shows a bias in favour of the selection of the longer fibres, and is therefore inferior to the method of selecting small bunches of fibres from different parts of the sliver, and testing every fibre in each bunch so selected.

(2) The mean value (i.e. the arithmetic mean) is usually satisfactory as a single value representing all the test-values obtained for a sample, but in the case of fibre-rigidity, for which the distribution is extremely asymmetrical, caution must be exercised in the use of the mean value as it is greatly affected by high individual values which are sometimes *ten times* as large as the arithmetic mean.

(3) In the case of fibre-length, fibre-width, and convolutions, which give nearly symmetrical frequency-distributions, the mean value and the probable error of a single observation are quite sufficient to indicate the composition of a sample. But in the case of fibre-strength, and more particularly in the case of fibre-rigidity, it is desirable to indicate the composition of a sample by the upper and lower quartiles, in addition to the mean value.

(4) The degree of reliability of small samples is indicated in the following table, which shows the total range, expressed as a percentage of the mean, for which the odds are as indicated that the mean of a random sample of the given size will lie therein—

Range (% of Mean) for which the Odds are as shown that the Mean of a Random Sample will lie therein

Fibre-property	Odds	Size of Sample				
		200	300	400	500	600
Fibre-length ...	20:1	18	16	13	11	9
Fibre-width ...	20:1	4	2·7	2	—	—
Convolutions ...	20:1	30	24	20	19	18
Fibre-strength ...	20:1	40	23	17	15	13
Fibre-rigidity ...	5:1	—	60	55	48	44

Thus from column 3 we see that the odds are 20:1 that the mean of a random sample of 200 fibres will lie within a range of 4% of the mean value of the

fibre-width; this is equivalent to 2% on either side of the mean, seeing that the distribution of values of fibre-width is symmetrical.

(5) In the selection of a certain size of sample as representative, we are guided partly by the degree of reliability of the result for that size, and also by practical consideration of the difficulties of making a very large number of tests. Bearing both these points in mind we consider the following are the minimum numbers of tests which should be made in the determination of the several fibre-properties by the methods described in Part I—

Fibre-property	No. of Fibres for Representative Sample	Total Range (% of Mean) for which the odds are 20 to 1 that the Random Sample will lie therein
Fibre-length .	500	11
Fibre-width ..	300	2·7
Convolutions ..	500	19
Fibre-strength ...	500	15
Fibre-rigidity ..	500	48 (odds 5 1)

(6) The results obtained in this investigation relate for the most part to Surat 1027 A.L.F. only. But as this cotton was specially selected because previous tests had shown that its individual test-results displayed great variation, it may be inferred that the results obtained from any given number of tests of a certain property of another cotton will be at least as reliable as those obtained from the same number of tests of the same property of Surat 1027 A.L.F.

I—INTRODUCTION

It was pointed out in Part I[1] that the experiments discussed in this series of papers had their inception in the desire to find answers to the following three questions concerning the sampling of cotton fibres—

(1) How may we obtain a satisfactory sample ?

(2) How many fibres constitute a satisfactory sample ?

(3) What is the degree of reliability of the results obtained for a value of a fibre-property ?

The difficulty of answering these questions arises from the great variation of properties from fibre to fibre; in Part II therefore we examined this variability as a necessary prelude to the answering of the three questions. We found that the different fibre-properties do in fact differ from one another both in the nature and degree of their variability, and in the present Part we proceed to utilise the results obtained in Part II in seeking the solution of our main problems.

As explained by one of us in a previous paper[2] the determination of the size of a representative sample is a comparatively simple matter if the distribution of the individual values can be represented by a normal curve For, in this case, by the analysis of the results for a very large sample—taken to represent the bulk—we can find the value of the probable error (e) of a single observation, which we may express as a percentage of the mean. It is to be noted that the probable error of a single observation is a measure of the variability of the sample, and, so long as the sample is not too small, its value will be approximately the same whatever the actual size of the sample. This is not the case for the probable error of the *mean* value for any sample, for this probable error is found by dividing the probable error of a single observation by the square root of the number of tests, n, so that by suitably increasing n we may make the probable error of the mean as small as we please. Now when dealing with a variable property we can only define a satisfactory

sample in terms of odds; we regard as a satisfactory sample one for which the probability is high that its mean value does not differ from the mean of the bulk by more than a certain amount. The "high probability" and "permissible difference from the mean of the bulk" are both fixed arbitrarily. Thus we may decide to accept a certain size of sample as satisfactory if the odds are 20 to 1 that its mean will not differ from the mean of the bulk by more than 6% on either side. Now from the value of the probability-integral for a normal distribution we find the odds are 20 to 1 that the mean of any sample of a given size will lie within the limits denoted by approximately three times the probable error of a mean of a sample of that size; hence with a "high probability" of 20 to 1 and a "permissible difference from the mean of the bulk" of 6% on either side, we must so choose n that the probable error of the mean $=\frac{6}{3}=2\%$ of the mean. But, for a normal distribution, if e is the probable error of a single observation, then the probable error of the mean $=\frac{e}{\sqrt{n}}$, so that in the present case $\frac{e}{\sqrt{n}}=2\%$ of the mean, whence $\sqrt{n}=\frac{e}{2}$, and $n=\frac{e^2}{1}$.

More generally, if we wish the mean of our sample to be correct with high probability within $x\%$ on either side of the mean of the bulk, and if we wish the odds against the sample-mean differing from the bulk-mean by this amount to be the same as apply to its not differing from the bulk-mean by more than m times the probable error of the mean, then we must so choose n that the probable error of the mean $=\frac{x}{m}$.

Hence $\frac{e}{\sqrt{n}}=\frac{x}{m}$, or $n=\frac{m^2e^2}{x^2}$

This formula for calculating n depends upon the following assumptions—

(1) That the number of observations forming the original sample, from which the probable error of a single observation is calculated, is sufficiently large.

(2) That the observations are distributed in accordance with the normal law of error; and

(3) That the conditions of "simple sampling" are satisfied, viz.—[3, 4]

(*a*) Every observation contributed to the sample may be regarded as independent of every other.

(*b*) "There is no essential difference between the localities" from which the observations are drawn, nor, if the observations have been made at different epochs, must any essential change have taken place during the period over which the observations are spread.*

*On this point "Student" remarks[5]—After considerable experience I have not encountered any determination which is not influenced by the date on which it is made; from this it follows that a number of determinations of the same thing made on the same day are likely to lie more closely together than if the repetitions had been made on different days. It also follows that if the probable error is calculated from a number of observations made close together in point of time much of the secular error will be left out, and for general use the probable error will be too small.

(*c*) "The conditions that regulate the appearance of the character observed are not only the same for every sample, but for every individual in every sample."

Let us examine how far these conditions apply to the problem in hand—

(1) The number of observations forming the original sample is large, as from 3,000 to 4,000 fibres were examined for each of the fibre-properties.

(2) As pointed out in Part II, none of the fibre-properties except fibre-width conforms strictly to the conditions of the normal law; in fact, fibre-strength and fibre-rigidity give decidedly skew distributions.

(3) (*a*) This condition is only partly satisfied, for although any particular bunch of the well-mixed fibres may be regarded as a random sample, yet there is a bias in selecting the successive fibres from a single bunch for testing, longer fibres being taken first; hence there is an accumulation of longer fibres among the earlier tests of a bunch of fibres, and also an accumulation of shorter fibres among the later tests; and the means of sets of successive tests will tend to be high or low according as they include a large proportion of the earlier or the later tested fibres.

(*b*) and (*c*) The observations extended over a period of more than a year, during which time it was not possible to maintain exactly the same conditions for the examination of every fibre. Moreover, the individual observations may be affected by instrumental or other kinds of persistent errors which cannot be accounted for by the errors of simple sampling.

In view of all these limitations we are compelled to derive our measures of reliability of the results from the actual study of small samples. The results of this investigation are given in the following pages; for purposes of comparison, however, we have indicated in each case the results that might have been expected if the distribution of the means had been normal, with a probable error of a single observation calculated from that possessed by the whole material.

II—METHODS OF INVESTIGATION

(i) *General Considerations*—A satisfactory sample is one which is completely representative of the bulk from which it is drawn; moreover, its size should be such that there is a high degree of probability that samples of similar size will be similarly constituted. Now, if a small sample is really representative it will have approximately the same arithmetic mean and standard deviation as a large sample; this will happen if the percentage frequency-distributions of the small and large samples are identical. Consequently we may employ three methods of investigation for finding the size of a representative sample, viz.—

(i) A comparison of the mean values of small samples of various sizes with the mean value of a large sample.

(ii) A comparison of the dispersions of values of small and large samples.

(iii) A comparison of the actual frequency-distributions of small samples with the theoretical frequency-distribution of a large sample.

For the purpose of determining the smallest size of sample which may be regarded as satisfactory, we might lay down the condition that the mean value for any property must be correct to within a certain percentage of the value for a very large sample; but if we make the limits the same for every fibre-property we encounter certain practical difficulties owing to the differences in variability of the different properties. Practical considerations may make it necessary for us to adopt fairly wide limits for such a variable

property as the fibre-rigidity, and if we were to adopt the same limits for a much less variable property, we should need to make only a few tests of the latter. But as there would be no practical difficulty in increasing the number of tests in this case, there is obviously no reason why we should not do so, and so attain a higher order of accuracy. Thus by means of the first method we shall determine the odds applicable for samples of different sizes to fall within certain definite limits; and then, bearing in mind these practical considerations, we shall decide what size of sample may reasonably be chosen and the odds and limits which apply to that size of sample.

We shall apply somewhat similar considerations to methods (ii) and (iii), but in these cases we shall finally indicate the magnitudes of the differences that are to be expected in the dispersions of values and in the frequency-distributions of the smallest samples whose sizes have been indicated as satisfactory by the first method.

It may be observed that even if our small sample has the same arithmetic mean and standard deviation as a large sample, we cannot be certain that other small samples will be similar; we must first find out the extent to which such small samples differ from one another, as one single small sample may be merely a particular case which happens to resemble the large sample. For each particular size of small sample, therefore, it is necessary to ascertain what is the distribution of a large number of such small samples. In order to obtain this large number of samples in the present investigation, the "moving-mean" method was adopted. This method will be clear from the following example—

Three thousand fibres were tested for fibre-strength; in finding the mean values of sets of 100 tests each, the mean was found of the first 100 test-values in the order of sampling; the first test-value was then discarded, and the 101st test-value included instead, so as to make the total number of values 100 as before, and the new mean was calculated. Next, the second test-value was also discarded, and the 102nd test-value included instead, and the third mean-value of 100 tests was calculated. By thus discarding the test-values one at a time, and making up the size of the sample by the inclusion of later test-values, a mean value of 100 tests was obtained each time a test-value was discarded; and as all the 3,000 test-values were discarded in turn, we were able to obtain 3,000 mean valuès of 100 tests each. In a similar way we obtained 3,000 mean values of groups of 200, 300, 400, 500, and 600 tests.

The same method has also been used in a slightly modified form; thus, in some cases the 3,000 test-values have been divided into 30 successive and independent groups of 100 each; the mean values have been found for each of the 30 groups, and the 30 independent means so obtained have been combined by this moving-mean method so as to give 30 means respectively for 200, 300, 400, 500, and 600 tests.

It is evident that the 3,000 mean values, of 100 and multiples of 100 tests, must be strongly correlated, and this has to be borne in mind in the interpretation of the results.

We will now briefly review the three methods of finding a representative sample.

(ii) *Method (i)—Comparison of the mean values of small samples with the mean value of a large sample*—In this method of finding the size of a representative sample, large numbers of mean values for samples of 100, 200, 300, 400, etc., are obtained by the moving-mean method. These mean values are

arranged in the form of a frequency-distribution for each size of sample, using the same class-interval throughout. It is found that as the size of the sample is increased, the frequency-distribution becomes more and more regular and symmetrical. By inspection of the frequency-distribution we ascertain what proportions of the means lie between certain assigned limits; we thus obtain the odds that any single mean of a sample of given size will lie between these limits. The odds applicable to the same limits for the means of samples of the same size, normally distributed with a probable error of a single observation calculated from that of the whole bulk of the material, are also given in order that the experimentally ascertained odds may be compared with the purely theoretical normal odds.

(iii) *Method (ii)—Comparison of the dispersions of values of small and large samples*—This method of finding the representative sample depends upon the fact that the dispersion of values of a sample tends to equal that of the whole population more and more as the size of the sample is increased. In the present paper the standard deviation is used as the measure of dispersion. Standard deviations are obtained for sets of 100 tests each, and multiples of sets of 100 (200, 300, 400, etc.); as previously indicated, the mean standard deviation for a given size of subsample tends to equal that of a large sample (3,000 values) more and more as the size of the subsample increases; moreover, the greater the size of the subsample, the smaller become the differences between the standard deviations of the individual subsamples of the given size, and hence the smaller becomes the standard deviation of these standard deviations.

The standard deviations for sets of 100, 200, 300, 400, and 500 tests for the various fibre-properties are given in Tables II, VI, IX, and XII. For the calculation of these standard deviations the 3,000 test-values are divided into 30 successive and independent groups of 100 test-values each, taken in the order of sampling; frequency-distributions of each set of 100 values are obtained, using the same class-interval throughout; we then take an *arbitrary mean which is kept the same for all the* 30 *sets*, and the standard deviation for each set is computed as explained in Part II (Technological Bulletin, Series B, No. 6, page 36, or *Journal of the Textile Institute*, Vol. XXI, 1930 T360). In this way we obtain 30 values of $\nu_1'\left(=\dfrac{\Sigma(mv)}{N}\right)$ and 30 values of ν_2' (second moment about the arbitrary mean); these values of ν_1' and ν_2' are next suitably combined by the moving-mean method to give the new ν_1' and ν_2' for any multiple of 100 tests, and after applying the proper corrections for arbitrary mean and grouping, μ_2 is obtained, the square root of which is the standard deviation. The method is not only simple but it also provides a check on the arithmetic, for which the algebraic sum of all ν_1''s for sets of 100, must be equal to the algebraic sum of all ν_1''s for multiples of 100 tests; similarly the sum of all ν_2''s for sets of 100 must be equal to the sum of all ν_2''s for multiples of 100.

(iv) *Method (iii)—Comparison of the actual frequency-distributions of small samples with the theoretical frequency-distribution of a large sample*—A number of samples of each standard size (100, 200, 300, 400, etc., test-values respectively) are taken out of the 3,000 test-values and the frequency-distribution for each sample is found. By comparing the distributions of the various samples of each given size with one another and with the theoretical distribution of 3,000 test-values, we can infer the minimum size of small sample which

may be taken as representative of the population. As previously indicated, this minimum limit of the size depends upon the percentage error, or departure from fitness, that we arbitrarily decide to regard as insignificant for our purpose. In order to indicate the closeness of fit by some mathematical index we use a certain quantity Δ, whose square, Δ^2, is calculated from the percentage distributions in exactly the same manner as χ^2 is calculated, as explained in Part II.[6] We shall call Δ "the coefficient of fitness." For the evaluation of Δ, the percentage frequency-distribution of a subsample and the theoretical percentage frequency-distribution are placed side by side, the number of classes being the same in both cases. For each class the difference δ is found between the theoretical value y and the observed value of the sample; the square of each such difference is divided by the corresponding theoretical value y. Then Δ equals the square root of the sum of the quotients thus obtained,

$$\text{i.e. } \Delta = \sqrt{\Sigma\left(\frac{\delta^2}{y}\right)}.$$

In an ideal case Δ would be zero, but in practice owing to unavoidable sampling errors, it always has some positive value which becomes less, however, as the number of tests is increased.

Instead of Δ we might use a somewhat simpler quantity d, the total of the absolute values of the deviations between the observed and theoretical percentage frequencies. Hence $d = \Sigma(\delta)$, and as the total of the frequencies themselves is necessarily 100 (since the frequencies in the class-intervals are expressed as percentages of the total), we may regard d as a measure of the total percentage deviation of the observed from the theoretical frequencies.

Now it can be shown that if the deviation between the observed and theoretical percentage frequencies, expressed as a percentage of the theoretical percentage frequencies, is the same for each class-interval, then $\Delta = \frac{d}{10}$. But in any actual case the percentage deviations are not all equal for the various class-intervals, and, as a consequence, the value of Δ is always greater than $\frac{d}{10}$. We therefore deduce that, for a given value of Δ, d is never greater than 10Δ.

In applying this method we have used the simpler quantity d in all cases, but for the fibre-properties of length and strength we have also used Δ.

III—DISCUSSION OF RESULTS

In Part II we found from an analysis of some 3,000 test-results the theoretical frequency-distribution for each fibre-property; from this theoretical frequency-distribution we have calculated the percentage frequency-distribution of a "perfect" sample, and have compared with this the observed percentage frequency-distributions of sets of 100, 200, 300, etc., test-values. The values of the total percentage deviation (d), and of the coefficient of fitness (Δ), are given in Tables III, IV, VII, X, XIII, XIV, and XVI. These tables, together with the tables of mean values and probable errors (single observation) of groups of 100, 200, 300, 400, etc., for the different fibre-properties are given in the Appendix (page T47 *et seq.*).

The different properties will now be considered separately in the following order—(1) Fibre-length; (2) fibre-width; (3) convolutions per fibre; (4) fibre-strength; (5) fibre-rigidity.

(1) Fibre-length

As has already been pointed out in Part I, two methods were used for the sampling of fibre-length. For the first 1,000 tests, fibres were picked singly from the prepared sliver, but for the subsequent tests small bunches were taken from the sliver, and all the fibres in each bunch were tested: In the discussion which follows we shall refer to the two methods as "Sampling Method A" and "Sampling Method B" respectively. We will first discuss the results for the last 3,000 tests of "Sampling Method B" in relation to questions (2) and (3), page 118, and afterwards compare the results obtained by the two methods of sampling for the light they shed in the first question.

(i) *Application of Method* (*i*)—*Comparison of mean values of small and large samples*—Table I gives the mean values of sets of 100, 200, 300, 400, 500, and 600 tests, based on the 30 successive and independent means of 100 tests each. With the increase in the bulk of the sample, the different mean values agree more amongst themselves and with the mean (2·26) of the whole sample (3,000 tests); the ranges of values for sets of 100 and 600 are 2·56–1·98 and 2·36-2·16 respectively. In order to study the distributions of mean values of different samples, all the observations were divided into 150 groups of 20 values each, and the mean value for each group obtained. From these the mean values for groups of 100, 200, 300, 400, 500, and 600 tests each were obtained by the moving-mean method. The results are embodied in Table I below in the form of a frequency-distribution of the values for each size of subsample—

Table I

Frequency-distributions of Mean Values of Fibre-length for Sets of 100, 200, 300, 400, 500, and 600 Tests obtained by the Moving-mean Method from 3,000 Tests

Mid-point of Class-interval	100	200	300	400	500	600
Cms						
1·90	1	–	–			
1·95	4	—	–	–		
2·00	6	4	—	—		–
2·05	6	2	5	1	—	
2·10	7	7	5	4	– –	–
2·15	19	20	7	4	12	5
2·20	24	28	35	46	40	48
2·25	17	27	48	41	44	42
2·30	16	22	20	26	26	31
2·35	13	15	10	13	22	24
2·40	14	10	11	15	6	—
2·45	9	10	7	– –	—	–
2·50	6	5	2		—	—
2·55	7		– –	—	– –	—
2·60	1	—	—		—	—
Mean	2·260	2·260	2·259	2·259	2·258	2·257
S.D.	0·1512	0·1112	0·0906	0·0719	0·0632	0·0547
$\sigma/\sqrt{n}$	0·0499	0·0353	0·0288	0·0249	0·0223	0·0203

For each size of sample there is a great difference between S.D., the standard deviation calculated from the 150 mean values and $\sigma/\sqrt{n}$, the standard deviation calculated from σ, the standard deviation of the whole population (3,000 values). This is largely due to the fact that the selection of successive fibres for testing was not completely random (see (3) (*a*) page T20).

though contributory causes are no doubt the correlation between successive means, and some error of measurement, arising from variation in the unmeasured length of the ends of the fibres embedded in the wax used for mounting.

Samples of size 100 show great variation and irregularity, while other sizes of sample are comparatively symmetrical and concentrated round the mean. This is also shown by the values of standard deviation of the mean for the set of samples of each size; the standard deviation rapidly decreases with the increase in the size of the sample; the value 0·0719 for 400 tests is less than half the value 0·1512 for 100 tests, and the change beyond 400 tests is very small. Out of the total number of 150 groups, the numbers of groups for different samples lying between certain limits are as follows—

Size of sample ...	100	200	300	400	500	600
Percentage number of samples between 2·175–2·325						
Actual	38	51	69	75	73	81
Expected from the value of $\sigma/\sqrt{n}$	87	96	99	100	100	100
Percentage number of samples between 2·125–2·375						
Actual	59	77	80	87	96	100
Expected from the value of $\sigma/\sqrt{n}$	99	100	100	100	100	100

From these figures it appears that the chances are actually 3 to 1 that the mean of a sample of 400 or 500 tests will be within 3·5% on either side of the mean of the whole population, and that the odds are 4 to 1 for 300 tests, 6·7 to 1 for 400 tests, 24 to 1 for 500 tests, and practically certain for 600 tests, that the mean will not differ from the mean of the whole population by more than 5·5% on either side. And as in general we should consider it undesirable for the fibre-length to be subject to a possible error of more than 5% we deduce from these results that it is necessary to take at least 500 fibres for determining the fibre-length by this method.

(ii) *Application of Method (ii)—Dispersion of values of small and large samples*—Table II gives the standard deviations for the different samples, and from these it can be seen that as the size of the sample is increased from 100 to 600 tests, the mean standard deviation gradually rises from 0·4722 to 0·4954, and approaches the standard deviation of the whole population, viz. 0·4986. The arithmetic mean of the 3,000 tests is 2·26 cm., so that the standard deviation of the whole population is 21·0% of the arithmetic mean. The ranges of the values of the standard deviations for 100 and 600 tests are 0·349–0·661 and 0·453–0·557 respectively. The values of the standard deviations for the various sizes of subsample are given below—

Size of sample ...	100	200	300	400	500	600
Mean standard deviation (cm.)	0·4722	0·4841	0·4895	0·4918	0·4945	0·4954
S.D. of S.D.'s (cm.) ...	0·0627	0·0485	0·0385	0·0341	0·0319	0·0301
S.D. (% of arithmetic mean) ...	2·77	2·15	1·71	1·51	1·41	1·33

These figures show that with the increase in the size of sample, the standard deviation of the standard deviations rapidly decreases, until for a sample of size 500 it is only 1·41% of the arithmetic mean.

(iii) *Application of Method (iii). Departure from fitness*—The observations were divided into 30 independent groups of 100 values each in the order of sampling. Frequency-distributions for each of these groups were obtained using the same class-interval (0·3 cm.—the same as used in curve-fitting in Part II) and the same number of class-intervals (11). The 30 frequency-distributions so obtained were then combined, class by class, in groups of 2, 3, 4, and 5 respectively by the moving-mean method, so as to give the

frequency-distributions for sets of 200, 300, 400, and 500 tests. The theoretical percentage distribution was obtained from the normal curve fitted to the observations. The values of total percentage deviations d and of coefficients of fitness Δ for the frequency-distributions of the various sub-samples are given in Tables III and IV respectively, from which it can readily be seen that both d and Δ decrease as the size of the sample is increased. The ranges of the values of Δ for samples of 100 and 500 are 8·71–2·28 and 4·00–1·47 respectively. The mean values of d and Δ for the different sizes of sample are given below—

Size of sample ...	100	200	300	400	500
Mean value of Δ	4·51	3·32	2·80	2·49	2·24
Mean value of d	30·6	23·4	19·1	17·0	15·2

From these figures we see that for samples of size 500 the mean departure from fitness (Δ) is only 2·24, and the mean total deviation (d) is only 15·2 per cent.

(iv) *Comparison of methods of sampling*—The mean value for the first 1,000 tests is 2·54 cm., whereas for the second, third, and fourth 1,000 tests the mean values are 2.26, 2.29, and 2.22 cm respectively. The difference between the mean of the first 1,000 and the next highest mean of 1,000 tests (the third 1,000) is 0·25; whereas, excluding the first 1,000, the greatest difference between the mean values of any other pair of 1,000 tests is only 0·07, or less than one-third of the former difference, which can hardly therefore be attributed to fluctuations of random sampling; moreover—

The mean value of first 1,000 tests		$2·54 \pm ·0082$
,, ,, second ,,		$2·26 \pm ·0118$
Difference between means		$0·28 \pm ·0144$

The difference between the means is *about* 20 *times* its probable error and so we cannot regard it as due to fluctuations in *random* sampling only; the difference is doubtless due to a sampling bias in favour of the long fibres by sampling method A, at the time of taking fibres from the prepared sliver.

We may now compare the results of the first 1,000 and the last 3,000 tests. The frequency-distributions of mean values of sets of 100, 200, 300, and 400, obtained by the moving-mean method for the first 1,000 tests, are given in Table II—

Table II

Frequency-distributions of Mean Values of Sets of 100, 200, 300, and 400 Tests obtained by the Moving-mean Method—Fibre-length (first 1,000 Tests)

Mid-point of Class-interval	100	200	300	400
2·30	4	—	—	—
2·33	31	—	—	—
2·36	27	—	—	—
2·39	35	—	—	—
2·42	56	7	—	
2·45	58	148	—	—
2·48	53	38	132	—
2·51	94	149	214	363
2·54	146	110	234	332
2·57	126	297	296	223
2·60	178	220	106	82
2·63	113	31	18	—
2·66	71	—	—	—
2·69	8	—	—	—

These frequency-distributions, compared with those given in Table I for the last 3,000 tests, are more irregular and skew. It is interesting to note that the region 1·90–2·30, which contains, even in the case of samples of size 100,

about 67% of the values in Table I, is altogether missing in Table II. This clearly shows the effect of bias in the selection of fibres in first 1,000 tests; as a consequence of the elimination of the short-length fibres in these tests, there is less variation among those that are selected in the sampling; and for subsamples of even 300 tests no less than 98% of the mean values are included within the range 2·465–2·615, so that the chances are 49 to 1 that, by this "A" method of sampling, the mean value of a sample of only 300 tests will be within 3% on either side of the mean of the whole population. While the method of measuring individual fibres can hardly be recommended against the present-day Sorter methods, in which the number of fibres used in the sample is so very much greater than is possible by the individual-fibre methods, yet some method of the latter kind has occasionally been used. Thus[7] "Cobb developed a very exact but laborious method of measuring fibres. The fibres were pulled individually and at random from the mass, projected with a lantern on a screen, and the enlarged figure measured by a map tracer. Two hundred fibres are found to give an accurate representation of the Cotton." Unfortunately, the evidence is not given on which this conclusion is based. From our previous discussion, it is clear that we cannot regard the conclusion as applicable generally; and it may be further pointed out that under these conditions, owing to the presence of the kinks in the fibres, the mean-length obtained by Cobb's method is likely to be much greater than that obtained by measurement with a microscope or telescope. We conclude that the sampling method "A" is defective because there is a tendency on the part of the experimenter unconsciously to select long fibres, causing the mean value to be higher and the variability less. The second sampling method "B" enables all the grades of fibre to be adequately sampled; and the sample of satisfactory size must contain at least 500 fibres, in which case the odds are 24 to 1 that the mean will not differ by more than some 5% from the mean of the whole population. A somewhat lower result was obtained by Morton,[8] who states, with reference to a series of tests on 15 cottons of various types, that for the length measurements "each mean involved observations on approximately 500 hairs, taken at random, so that the probable error of the mean was of the order of 1%"; hence, in this case, if the means are normally distributed, the odds are 24 to 1 that the mean will not differ by more than 3·2% from the mean of the whole population.

(2) Fibre-width

(i) *Variation among samples*—The 3,000 test-values were divided into 30 successive and independent groups of 100 each, and the mean value obtained for each group. The 30 means of 100 tests were then combined by the moving-mean method so as to give 30 mean values for sets of 100, 200, 300, 400, and 500 tests; these mean values are given in Table V. On examining the means for the independent sets of 100 tests (col. 2), it will be found that the whole column can be divided into three distinct regions, I–X, XI–XX, and XXI–XXX, comprising the first, second, and third 1,000 tests respectivly. It may be noted that the lowest value in the first region is 169·2 (mean value of fifth 100 tests) and the highest value is 180·7; and that in the second region, even the lowest value 182·4 (mean value of fifteenth 100 tests) decidedly exceeds the highest value in the first region. This distinct division into three parts is maintained even when the test-values are grouped into the larger samples, although the fluctuation amongst individual values then becomes less. The frequency-distributions, of 3,000 mean values

each, of sets of 100 and of 200 tests—obtained by the moving-mean method—present three well-marked peaks, showing that so far as mean values are concerned we are dealing with a heterogeneous mass. The heterogeneity is not unexpected in the case of the first 1,000 fibres, for, as we have already seen, these constitute a sample materially different from the second and third 1,000 fibres; the sampling was biassed in favour of greater length, and as greater length and smaller width are generally associated together, it is not really surprising that the mean values for fibre-widths of sets of 100 of the first 1,000 fibres are comparatively low, and that the mean value for the first 1,000 fibres is 173·4 (10^{-5} cm.), whereas the mean values for the second and third 1,000 tests are 186·04 and 180·44 (10^{-5} cm.) respectively.

But even when we have separated off the first 1,000 test-values, we find that the frequency-distribution of the means of sets of values taken from the remaining 2,000 test-values still presents two distinct peaks. Now the mean values of the second and third 1,000 tests are respectively $186{\cdot}04 \pm {\cdot}408$ and $180{\cdot}44 \pm {\cdot}426$, and the difference between them is $5{\cdot}60 \pm {\cdot}590$; this difference is about ten times its probable error, so that it cannot be wholly ascribed to errors of random sampling. In point of fact, the second and third 1,000 tests were made at widely different values of the atmospheric humidity, which generally ranged between 70 and 80 (mean 75%) for the second 1,000 tests, and between 40–65 (mean 50%) for the third 1,000 tests. In view of the results given by Clayton and Peirce,[9] there can be but little doubt that the higher value obtained for the second 1,000 tests is due to the higher humidity prevailing when they were carried out. For these reasons, in investigating the reliability of mean values for small samples, we have confined our attention to the results for a single 1,000 tests, and have selected the second 1,000 tests because these gave an excellent fit to the theoretical curve by the "χ^2, P" test.[10]

(ii) *Application of Method* (*i*). *Comparison of mean values of small and large samples*—Table V shows the mean values of sets of 100, 200, 300, 400, and 500 tests, based on the 30 successive and independent means of 100 tests each. In order to examine the reliability of mean values of small samples, 1,000 mean values have been obtained by the moving-mean method for sets of 100, 200, 300, and 400 tests respectively, using all of the second 1,000 values for each set. The frequency-distributions of these mean values are given in Table III—

Table III

Frequency-distribution of Mean Values of Sets of 100, 200, 300, and 400 Tests, obtained by the Moving-mean Method—Fibre-width (second 1,000 Fibres)

Fibre-width 10^{-5} cm.	100	200	300	400
179	17	—	—	—
180	23	—	—	—
181	18	—	—	—
182	27	2	—	—
183	108	45	—	—
184	120	177	84	5
185	96	127	288	293
186	88	232	283	419
187	151	196	223	190
188	170	164	115	93
189	154	57	7	—
190	28	—	—	—
Mean ...	186·0	186·1	186·0	186·1
S.D. ...	2·68	1·60	1·13	0·89
$\sigma/\sqrt{n}$ ...	1·99	1·41	1·15	1·00

Except for the smallest size of sample there is fair agreement between the standard deviation, S.D., calculated directly from the means, and $\sigma/\sqrt{n}$, the standard deviation calculated from σ, the standard deviation of the whole population.

The samples of 100 fibres have given very irregular distribution and great variation, so that 100 fibres cannot be regarded as a satisfactory sample. Samples of 300 and 400 fibres give nearly symmetrical distributions. The mean for the whole 1,000 fibres is 186·04. The following are the numbers per 1,000 of the means for the various sizes of sample which lie within the ranges indicated—

Size of sample	100	200	300	400
Number of samples between 184·5–187·5—				
Actual	335	555	794	902
Expected from the value of $\sigma/\sqrt{n}$ ...	549	713	807	867
Number of samples between 183·5–188·5—				
Actual	625	896	993	1,000
Expected from the value of $\sigma/\sqrt{n}$ ...	791	924	970	988

These figures show that, for samples consisting of 300 and 400 fibres, 80 and 90% respectively of the means do not differ from the grand mean by more than 0·8% on either side, and that less than 1% differ from the grand mean by as much as 1·4% on either side.

We can therefore conclude that the limit of random sampling fluctuations for fibre-width for samples of 300 fibres is some 1·5% on either side of the mean, i.e. if two samples, each of 300 fibres, differ in their mean values of fibre-width by more than 3%, the difference cannot be regarded as due entirely to sampling error.

(iii) *Application of Method (ii). Dispersion of values of small samples*—Table VI gives the values of the standard deviations for sets of 100, 200, 300, 400, and 500 tests, taken from the whole population of 3,000 tests. It will be noticed that as the size of the sample increases, the fluctuations among individual standard deviations become less and less, the ranges for 100 and 500 tests being 14·7–23·3 and 16·3–22·3 respectively. The mean of the standard deviations gradually rises from 18·66 for 100 tests to 19·25 for 500 tests, and so approaches the standard deviation of the whole population, viz. 19·92, or 11·0% of the arithmetic mean. The values of the standard deviations for the different sizes of subsample are as follows—

Size of sample	100	200	300	400	500
Mean standard deviation (10^{-5} cm.) ...	18·66	18·88	19·03	19·12	19·25
S.D. of S.D.'s (10^{-5} cm.)	2·36	2·08	1·93	1·84	1·68
S D. (% of arithmetic mean)	1·31	1·16	1·07	1·02	0·94

Thus the standard deviation of the standard deviations decreases with increase in the size of sample, and for samples of size 300 is only 1·07% of the arithmetic mean.

(iv) *Application of Method (iii). Departure from fitness*—The second 1,000 test-values were divided into ten independent groups of 100 values each in the order of sampling; frequency-distributions were obtained for each of these groups using the same class-interval and the same number of class-intervals in each case. The ten frequency-distributions so obtained were then combined, class by class, in groups of 2, 3, 4, and 5 respectively by the moving-mean method, so as to give the ten frequency-distributions for sets of 200, 300, 400, and 500 tests. Table VII gives the values of total percentage deviation for the frequency-distributions of these sets of tests. The individual values rapidly decrease with increase of size of the sample, the

ranges for 100 and 500 tests being 36·0–17·6 and 14·0–8·8 respectively. The mean values of d for the different sizes of subsamples are given below—

Size of sample	100	200	300	400	500
Mean value of d	26·7	18·3	15·1	13·1	11·1

The mean value of the total deviation d is only 15·1% for samples of size 300, which from method (i) we take to constitute a representative sample.

According to Calvert and Summers,[11] 250 hairs chosen at random from all parts of the bulk constitute a representative sample, when the fibre-width is measured in only one place, viz. near the middle of each fibre; their probable error of the mean for 250 fibres is $0{\cdot}13\mu$, or $1{\cdot}3 \times 10^{-5}$ cm. But in our experiments ten measurements of fibre-width were made at intervals along each fibre, giving therefore a higher order of accuracy of the value for each fibre; reference to Table V shows in fact that in these circumstances the mean of the results for 100 fibres has nearly the same probable error, and therefore the same accuracy, as the mean for 250 fibres measured only once each.

(3) Convolutions

(i) *Application of Method (i). Comparison of mean values of small and large samples*—Table VIII gives the 30 mean values each of sets of 100, 200, 300, 400, 500, and 600 tests, the mean values for the multiples of 100 tests having been obtained by combining those for the 100 tests by the moving-mean method. With the increase in the size of the subsample, the individual values of the means for each subsample agree more and more among themselves and with the grand mean (88·9) of the whole 3,000 tests; thus the ranges of the means of samples of 100 and 600 tests are from 108·6±2·15 to 72·5±1·87, and from 99·5±0·87 to 82·7±0·82 respectively.

In order further to study the frequency-distribution of mean values of small samples, the mean values of 150 successive and independent sets of 20 values each have been calculated. By suitably combining these means by the moving-mean method, we have obtained 150 mean values for sets of 100, 200, 300, 400, 500, and 600 tests each. The results are embodied in Table IV—

Table IV

Frequency-distribution of Mean Values of Sets of 100, 200, 300, 400, 500, and 600 Tests, obtained by the Moving-mean Method—Convolutions (3,000 Tests)

Mid-point of Class-interval	100	200	300	400	500	600
70	3	—	—	—	—	—
73	4	1	—	—	—	—
76	9	9	2	—	—	—
79	5	8	9	5	—	—
82	17	13	18	21	25	17
85	23	35	34	27	24	34
88	25	17	22	43	49	51
91	14	16	25	15	18	14
94	16	25	11	15	14	14
97	13	8	15	10	12	13
100	8	13	14	14	8	7
103	7	3	—	—	—	—
106	5	2	—	—	—	—
109	1	—	—	—	—	—
Mean	88·86	88·86	88·86	88·94	88·79	88·82
S.D.	8·451	7·131	6·108	5·571	4·974	4·734
$\sigma/\sqrt{n}$	3·090	2·185	1·784	1·545	1·380	1·260

For each size of sample there is a great difference between the standard deviation S.D., calculated from the 150 means, and $\sigma/\sqrt{n}$, the standard deviation calculated from σ, the standard deviation of the whole population (3,000 values). The number of convolutions is strongly correlated with the fibre-length, and will have been subject to the same disturbing influences (page T25). A further possible cause of the dispersions of the means being much greater than would have been expected from the values of $\sigma/\sqrt{n}$, is that the number of convolutions is affected by changes in the relative humidity to which the fibre is subjected.

Samples of 100 and 200 test-results give very irregular frequency-distributions and show great variation, while samples of larger size give more nearly symmetrical frequency-distributions. The following are the numbers of the (150) means of the various sizes of sample which lie within the range 80·5 95·5—

Size of sample	100	200	300	400	500	600
Number of samples between 80·5–95·5—						
Actual	95	106	110	121	130	130
Expected from the value of $\sigma/\sqrt{n}$ ...	149	150	150	150	150	150

These figures show that for samples of 400 and 500 fibres, 81 and 87% respectively of the means actually lie within the range 80·5–95·5, i.e. within 9% on either side of the grand mean. We therefore conclude that it is necessary to test at least 500 fibres in order to have even a 7 to 1 chance that the mean obtained will not differ from the mean of a very large sample by more than 9% on either side.

(ii) *Application of Method (ii). Dispersion of observation-values of small samples*—Table IX gives the values of the standard deviations for sets of 100, 200, 300, 400, and 500 tests. As the size of the sample is increased, the fluctuations among individual standard deviations become less and less—the ranges for 100 and 500 tests being 22·9–34·6 and 26·9–33·3 respectively. The mean of the standard deviations gradually rises from 29·63 for 100 tests to 30·47 for 500 tests, and so approaches that of the whole population, viz. 30·90—or 34·8% of the arithmetic mean (88·9). The values of the standard deviations for the various sizes of subsample are given below—

Size of sample	100	200	300	400	500
Mean standard deviation	29·63	30·04	30·24	30·39	30·47
S.D. of S.D.'s	2·76	2·28	2·09	2·03	1·84
S.D. (% of arithmetic mean) ...	3·11	2·57	2·36	2·28	2·07

Thus the standard deviation of the standard deviations decreases with the increase in the size of the sample, and for samples of size 500 it is 2·07% of the arithmetic mean.

(iii) *Application of Method (iii). Departure from fitness*—The 3,000 values for the total number of convolutions per fibre were divided into 30 successive and independent groups of 100 each, and the frequency-distribution obtained for each of the 30 groups. The 30 frequency-distributions so obtained were then combined, class by class, in groups of 2, 3, 4, and 5 respectively, by the moving-mean method, so as to give 30 frequency-distributions each for sets of 200, 300, 400, and 500 tests. The theoretical percentage frequency-distribution was calculated from the normal curve fitted to the 3,000 observations. Table X gives the values of percentage deviation from fitness (d) for the frequency-distributions of the sets of 100, 200, 300, 400, and 500 tests. The mean values of d are comparatively large, and though the value of d decreases with increase in size of the sample, yet the fall in its value is not so

rapid as for other fibre-properties because the theoretical normal curve used as the standard of comparison is not a good fit to the observations. The mean values of d for the various sizes of subsamples are as follows—

Size of sample	100	200	300	400	500
Mean value of d	32·4	27·0	24·0	22·7	21·7

Thus the total deviation is as much as 21·7% even for a sample of 500 fibres.

(4) Fibre-strength

(i) *Skew distributions*—Before proceeding to determine the minimum size of a satisfactory sample, we may point out that fibre-strength differs greatly from any of the three properties previously considered in that, as shown in Part II, the dominant feature of its frequency-distribution is its decided skewness, arising from an excessive number of weak fibres in the sample; we will therefore first consider some of the consequences of this skewness. We found that the frequency-distribution of the 3,000 test-results of Surat 1027 A.L.F. was best fitted by Pearson's Type I. Unfortunately, tables are not available to show what fraction of the area of a curve of Type I is included between any given strength-limits, and we cannot therefore compare the odds indicated by the theoretical curve for any particular range of results with those actually obtained in the analysis of the 3,000 test-results. But although a curve of Type I gives the best "fit," yet the values of β_1 and β_2 also satisfy fairly accurately the conditions of a skew curve of Type III, for which extended tables of the probability-integral are available.[12]

The closeness of fit of the Type I, Type III, and normal curves will be apparent from Table V, which shows the percentage frequencies for each class-interval; the values for the normal curve have been calculated on the assumption that it has the same mean and standard deviation as found experimentally.

Table V

Percentage Frequency-distribution of the Fibre-strength of Surat 1027 A.L.F.

Strength	Observed	Type I	Type III	Normal
0– 0·9	3·9	3·7	6·2	(11·1)
1·0– 1·9	18·3	17·7	15·5	10·0
2·0– 2·9	18·4	19·9	19·3	14·0
3·0– 3·9	17·0	17·4	18·4	16·5
4·0– 4·9	14·1	13·6	13·5	16·3
5·0– 5·9	10·4	9·9	10·1	14·0
6·0– 6·9	6·6	6·8	6·7	8·7
7·0– 7·9	5·0	4·4	4·2	5·3
8·0– 8·9	2·5	2·8	2·6	2·6
9·0– 9·9	1·6	1·7	1·4	1·1
10·0–10·9	1·0	1·0	0·9	0·4
11·0–11·9	0·8	0·6	0·5	0·1
12·0–12·9	0·2	0·3	0·3	0·0
13·0–13·9	0·1	0·2	0·2	—
14·0–14·9	0·1	0·1	0·1	—
15·0–15·9	0·0	0·0	0·0	—

On comparing the values in Table V it is at once evident that Type I gives very good and Type III fairly good agreement with the observed distribution, while the normal distribution differs greatly from the observed, especially for low and high values of strength. As Type I gives the better agreement, its percentage-distribution has been taken to represent the constitution of Surat cotton in the comparison with the percentage-distribution of subsamples according to method (iii).

But for calculating the odds, we may use the tables of probability-integral applicable to Type III, and thus obtain Table VI, showing the theoretical chance of obtaining a prescribed deviation for any individual value of fibre-strength.

Table VI

Chance of obtaining certain Deviations in Individual Values of Fibre-strength. Cotton—Surat 1027 A.L.F. Mean of 3,000 Tests=3·91 grams

Strength (grams)	Strength in terms of mean value	Fraction of total area bounded by the ordinate through the corresponding value in Column 1	Odds against the occurrence of a deviation equal to or greater than that in Column 3	
			By Type III	By normal curve with the same mean value and the same standard deviation
0·5	·128	·01895	51·8 to 1	12·5 to 1
1·0	·258	·06218	15·1 to 1	8·2 to 1
1·5	·384	·13034	6·7 to 1	5·5 to 1
2·0	·511	·21711	3·6 to 1	3·8 to 1
2·5	·639	·31271	2 2 to 1	2·6 to 1
3·0	·766	·40983	1·14 to 1	1·9 to 1
3·5	·893	·49715	1·02 to 1	1·3 to 1
4·0	1·021	·40653	1·46 to 1	1 06 to 1
4·5	1·149	·32605	2·1 to 1	1·5 to 1
5·0	1·276	·27107	2·7 to 1	2·1 to 1
5·5	1·404	·21654	3·6 to 1	3·0 to 1
6·0	1·531	·17055	4·9 to 1	4·5 to 1
6 5	1·659	·13297	6 5 to 1	6·5 to 1
7·0	1·786	·10345	8·7 to 1	12·0 to 1
7·5	1·914	·08065	11·4 to 1	14·7 to 1
8·0	2·041	·06152	15·3 to 1	23·2 to 1
8·5	2·169	·04675	20·4 to 1	37·7 to 1
9·0	2·296	·03428	28·2 to 1	63·9 to 1
9·5	2·424	·02664	36·6 to 1	112·0 to 1
10·0	2·551	·02005	49·0 to 1	203·2 to 1
10·5	2·679	·01500	65·7 to 1	375·6 to 1
11·0	2·806	·01121	88·2 to 1	742·9 to 1
11·5	2·934	·00858	112·9 to 1	1546·0 to 1
12·0	3·062	·00615	161·6 to 1	3313·0 to 1
12·5	3·190	·00455	218·8 to 1	7721·0 to 1
13 0	3·317	·00336	296·6 to 1	13375·0 to 1
13·5	3·445	·00244	408·8 to 1	4200 5 to 1
14·0	3·573	·00179	557·7 to 1	107525·0 to 1
14·5	3·701	·00131	762·3 to 1	277777·0 to 1
15·0	3·830	·00096	1041·0 to 1	381730·0 to 1
16·0	4·086	·00050	1999·0 to 1	6502×10^3 to 1
17·0	4·340	·00027	3703·0 to 1	699×10^5 to 1
18·0	4·720	·00014	7142·0 to 1	83×10^7 to 1

The first column gives the values of strength in grams, in class-intervals of half a gram. Column 2 gives the values of the strength relative to the mean, obtained by dividing the corresponding values of fibre-strength in column 1 by 3·91, the arithmetic mean of the whole 3,000 test-results. The ordinate through a particular value of strength given in column 1 divides the total area, assumed to be unity, into two parts, one of which is less than half and the other greater; the value of the fraction less than half is shown in column 3.

From these figures the percentage constitution of the sample can be easily calculated by subtracting consecutive values and multiplying the result by

100. In this way we obtained the theoretical percentage frequency-distribution of fibre-strength given in Table V. As an illustration, we will calculate the percentage number of fibres having strengths from 3 to 4 grams, and from 4 to 5 grams, i.e. 1 gram below and above the mean, taken roughly at 4 grams. The fractions of the total area of the curve below 3 grams, above 4, and above 5 grams respectively, are—

$$\cdot 40983,\ \cdot 40653,\ \text{and}\ \cdot 27107.$$

Subtracting ·27107 from ·40653, we obtain 0·13546, which shows that 13·55 of the fibres have strengths between 4 and 5 grams. The median lies between 3 and 4 grams, so that in order to obtain the percentage of fibres between 3 and 4 grams, we have to subtract each of the values ·40983 and ·40653 from ·50000, and then add the results. We thus obtain the figure ·18364, so that 18·36% of the fibres have strengths between 3 and 4 grams, as compared with 13·55% between 4 and 5 grams.

In column 4 are given the values of odds against the occurrence of corresponding values of fibre-strength given in columns 1 or 2. It provides us with a useful index for the rejection of outlying observations. For example, the odds against the occurrence of 18 grams or more are 7,142 to 1, i.e. we should expect only one fibre in every 7,000 to have a strength of 18 grams or more. Hence if in testing 1,000 fibres we get one or more fibres having a strength of 18 grams or more, these values may be rejected. It may be noted that we cannot use Chauvenet's criterion or the more recent criterion given by Irwin[18] for this purpose as these criteria are applicable only in the case of a normal distribution.

For the sake of comparison we have given in the last column what the odds against the occurrence of each value of fibre-strength would be if the frequency-distribution were normal, with the same mean value and standard deviation; these figures differ very widely from those given by the skew distribution. For example, the "normal" odds against the occurrence of fibre-strength of 12·5 grams or more, are 7,721 to 1, i.e. we should expect only one fibre in about 8,000 to have this or a greater strength; on the other hand, the "Type III" odds against the occurrence of a fibre-strength of 12·5 grams or more, are 218·8 to 1, i.e. we should expect one fibre in about 220 to have this or a greater strength—or out of 3,000 fibres about 14 fibres should have a strength over 12 grams. Experimentally we found 15 fibres having a strength over 12 grams, which is in accord with the conclusions drawn from the skew curve. Again, guided by the normal distribution, we should reject all observations over 12 grams as doubtful; the "normal" odds against a fibre having a strength of 15 grams or more, are 381,730 to 1, so that we should not expect a single fibre out of 3,000 to have such a high strength, but experimentally we did get one such fibre, and this is within the expectation from the skew curve, as the odds against its occurrence in this case are only 1,999 to 1. These agreements with the deductions from the skew distribution are of course only to be expected, because the odds which we have applied are those of a particular skew curve which gives quite a good fit to the observed frequency-distribution.

It may further be noted that the rule that three times the standard deviation on either side of the mean includes practically all the deviations, holds good only in the case of the normal curve. In the case of the skew curve, while the range of three times the standard deviation may extend

beyond the limits of the actual distribution on the dwarf side of the mean, yet on the giant side the same range may be insufficient to include all the deviations. Taking the present example of fibre-strength, we find that the weakest fibre has a strength of 0·1 gram, which corresponds to a deviation from the mean of about 1·6 times the standard deviation or about half the usual range; the maximum strength is 15 grams, which corresponds to a deviation of about 4·6 times the standard deviation, or about one and a half times the usual range for the normal curve. Thus although the total range is again about six times the standard deviation, the curve is unduly elongated on the positive side and contracted on the negative side.

Another point worthy of note is that although the original distribution is very skew, yet the distributions of the means of samples become less and less skew as the size of sample is increased. Thus Table VII gives the frequency-constants of the frequency-distributions of various subsamples given in Table VIII. The variability, as given by the standard deviation, rapidly decreases as the size of the sample is increased—the value for 500 being about a quarter that for 100; and for 600, about one-third that for 200 tests.

Table VII

Frequency-constants of Frequency-distributions of mean-values of Subsamples, obtained by the Moving-mean Method

Size of Sample	Number of Samples	Mean grams	Median grams	Mode	Standard deviation (grams)	Skewness
1	3 000	3·91	3·50	2·255	2·357	·7020
100	3,000	3·916	3 843	3·761	0·5118	·3028
200	3,000	3·913	3·896	3·866	0·3363	·1417
300	3,000	3 914	3·901	3·871	0·2314	·1869
400	3,000	3·908	3·904	3 901	0·1686	·0410
500	3,000	3·914	3·911	3·911	0·1369	·0209
600	3,000	3·906	3·908	3 904	0·1234	·0204

The rate of change of variability becomes very slow at 500 tests. As is to be expected, therefore, the values of skewness likewise continually decrease with increase in the size of the sample, and are so small for samples of size 500 and 600 fibres as to indicate that the distributions are symmetrical and nearly normal.

We now proceed with our problem of finding the size of a representative sample—

(ii) *Application of Method* (*i*). *Comparison of mean values of subsamples with the mean value of a large sample*—Mean values were calculated for 30 successive and independent samples of 100 fibres each. These 30 mean values were then combined by the moving-mean method so as to give 30 mean values each for sets of 200, 300, 400, 500, and 600 tests. The results are given in Table XI, from which it will be seen that as the size of the subsample is increased, the mean values cluster more and more round the mean (3·91) of the whole 3,000 tests. The ranges for samples of 100 and 600 are 3·04–4·92 and 3·63–4·19 grams respectively.

In order to study the distribution of mean values, 3,000 mean values for each size of subsample were obtained by the moving-mean method. The results are given in Tables VII, VIII, and IX.

Table VIII

Frequency-distributions of Mean Values of Sub-samples obtained by the Moving-mean Method (3,000 Values)

Group (grams)	Mid-point of group grams	Samples of					
		100	200	300	400	500	600
2·65–2·75	2·7	18	—	—	—	—	—
2·75–2·85	2·8	25	—	—	—	—	—
2·85–2·95	2·9	12	6	—	—	—	—
2·95–3·05	3·0	38	12	—	—	—	—
3·05–3·15	3·1	57	10	—	—	—	—
3·15–3·25	3·2	61	41	—	—	—	—
3·25–3·35	3·3	104	39	—	—	—	—
3·35–3·45	3·4	104	86	16	10	—	—
3·45–3·55	3·5	141	166	166	82	—	—
3·55–3·65	3·6	269	274	214	116	124	61
3·65–3·75	3·7	385	261	260	166	221	248
3·75–3·85	3·8	320	380	509	662	483	702
3·85–3·95	3·9	245	493	651	855	1100	834
3·95–4·05	4·0	224	337	372	637	624	875
4·05–4·15	4·1	241	237	460	247	281	165
4·15–4·25	4·2	155	228	104	93	139	113
4·25–4·35	4·3	115	190	90	100	28	2
4·35–4·45	4·4	91	75	83	32	—	—
4·45–4·55	4·5	76	32	57	—	—	—
4·55–4·65	4·6	62	28	18	—	—	—
4·65–4·75	4·7	41	16	—	—	—	—
4·75–4·85	4·8	54	55	—	—	—	—
4·85–4·95	4·9	44	34	—	—	—	—
4·95–5·05	5·0	27	—	—	—	—	—
5·05–5·15	5·1	8	—	—	—	—	—
5·15–5·25	5·2	19	—	—	—	—	—
5·25–5·35	5·3	14	—	—	—	—	—
5·35–5·45	5·4	9	—	—	—	—	—
5·45–5·55	5·5	8	—	—	—	—	—
5·55–5·65	5·6	10	—	—	—	—	—
5·65–5·75	5·7	11	—	—	—	—	—
5·75–5·85	5·8	11	—	—	—	—	—
5·85–5·95	5·9	1	—	—	—	—	—

Table VIII gives the frequency-distributions of mean values for sets of 100, 200, 300, 400, 500, and 600. Samples of sizes 100 and 200 have very irregular distribution and great variation, so that these cannot be considered satisfactory samples. Samples of sizes 400, 500, and 600 respectively, give very nearly symmetrical distributions. The mean of the whole 3,000 tests lies in the group 3·85–3·95. The following are the numbers per 3,000 of the means for the various sizes of sample lying within the region 3·75–4·05—

Size of sample	100	200	300	400	500	600
Number of means between 3·75–4·05—						
Actual	789	1,210	1,532	2,154	2,207	2,411
Expected from the value of $\sigma/\sqrt{n}$	1,425	1,902	2,190	2,390	2,530	2,643

The great advantage of making 400 or more tests instead of 100 or 200 is at once apparent. Of the samples of size 500, some 74% have means which do not differ from the grand mean by more than 4% on either side, whereas, of the samples of size 100, the means of only 27% do not differ from the grand mean by more than 4% on either side. Thus the odds are 3 to 1 that the mean strength of any random sample of 500 fibres will not differ from the true

value by more than 4% on either side; the corresponding odds for a random sample of 600 fibres are 4 to 1, whereas for a sample of 100 fibres the corresponding odds are about 3 to 1 that its mean strength value *will* differ by so much from the true mean.

In view of the intrinsic interest of the skew-distribution of fibre-strength, we will examine somewhat more closely the range of odds applicable under different conditions to the various sizes of sample.

From what has already been said, it is evident that neither 100 nor 200 fibres can be regarded as a representative sample; we will therefore confine our attention to samples of size 300, 400, 500, and 600, remembering that the adequate size of the sample depends upon the accuracy we desire. Table IX has been drawn up to show the chance of obtaining any given deviation from the mean values for sets of 300, 400, 500, and 600.

For samples of size 300 the values of the fraction of total area which is bounded by the ordinate through the corresponding values given in column 3, have been calculated from the skew probability-integral by the help of Pearson's "Tables of Incomplete Γ-Functions"; for the samples of other sizes the "Tables of Normal Probability Integral"[14] have been used. It may be noted that the percentage deviation from the mean is readily obtained from the strength expressed as a fraction of the mean (col. 2), by subtracting the latter from unity and multiplying by 100.

For sizes of samples 500 and 600, the odds are very great against the occurrence of a mean value 4·45 grams or more, as will be seen from the following extract from Table IX—

Size of sample			Odds against occurrence of mean value of 4·5 grams or more
300	...	...	57·8 to 1
400	...	...	1,470 to 1
500	...	...	24,999 to 1
600	...	...	99,999 to 1

Hence, if we had large populations of means of 300, 400, 500, and 600 respectively we should expect 1 in 59 of the means of 300 tests to be as large as 4·5 grams; only 1 in 1,471 of the means of 400 tests; 1 in 25,000 of the means of 500 tests; and 1 in 100,000 of the means of 600 tests. Hence the mean value 4·5 grams marks the upper limit of sampling fluctuation for the means of samples of size 500 and 600, but not for the means of samples of size 300.

The following values are obtained from Table IX for the values of odds against the occurrence of a value 3·45 grams or less.

Size of sample			Odds against occurrence of mean value of 3·45 or less
300	...	...	80 to 1
400	...	...	314 to 1
500	...	...	2,560 to 1
600	...	...	9,999 to 1

Here again it is evident that the mean value 3·5 grams marks the lower limit of sampling fluctuation for the means of samples of size 500 and 600 but not for the means of samples of size 300.

At the bottom of Table IX are given the values of odds for mean values lying beyond the limits given by the ranges 3·75–4·05, 3·65–4·15, 3·55–4·25, and 3·45–4·35; these ranges correspond to extreme deviations of 8%, 13%, 18%, and 23% respectively, or to deviations of 4%, 6·5%, 9%, and 11·5% on either side of the true mean.

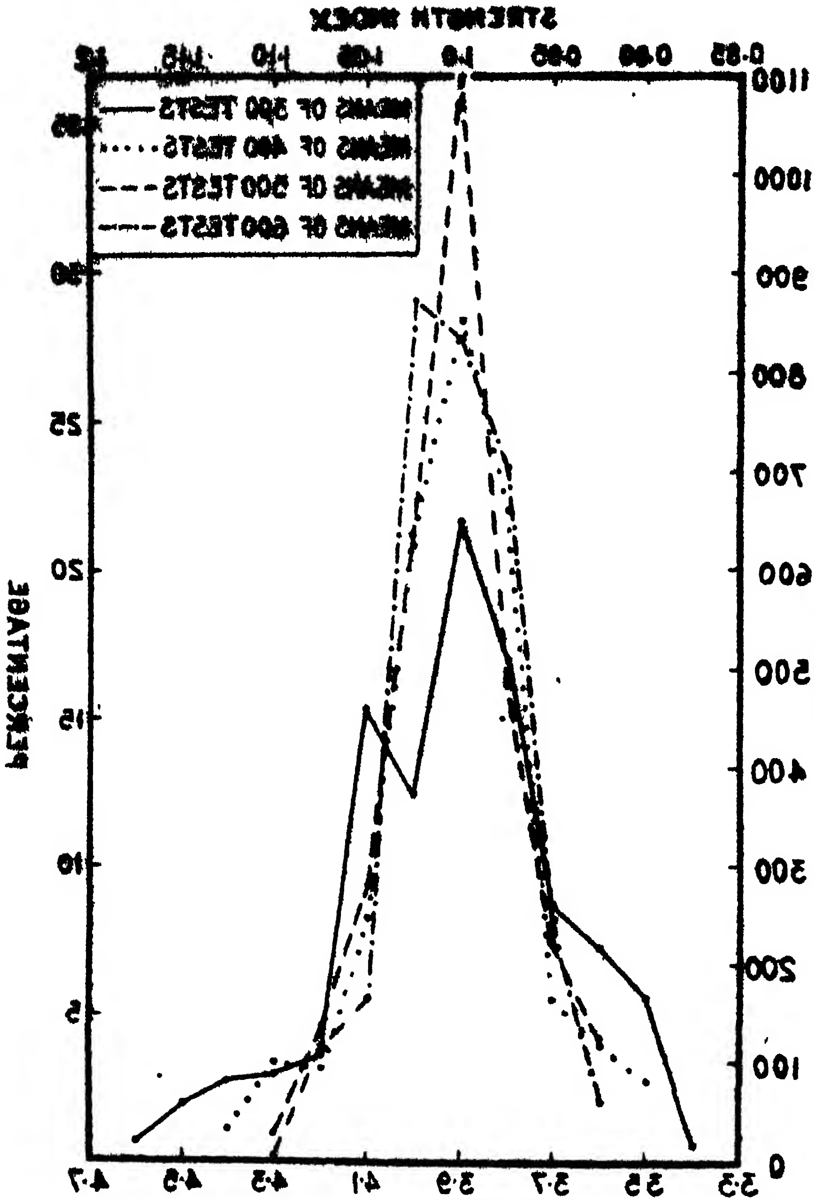

FIG. 1—Actual frequency-distribution of mean values of fibre-strength for Surat 1027 A.L.F.

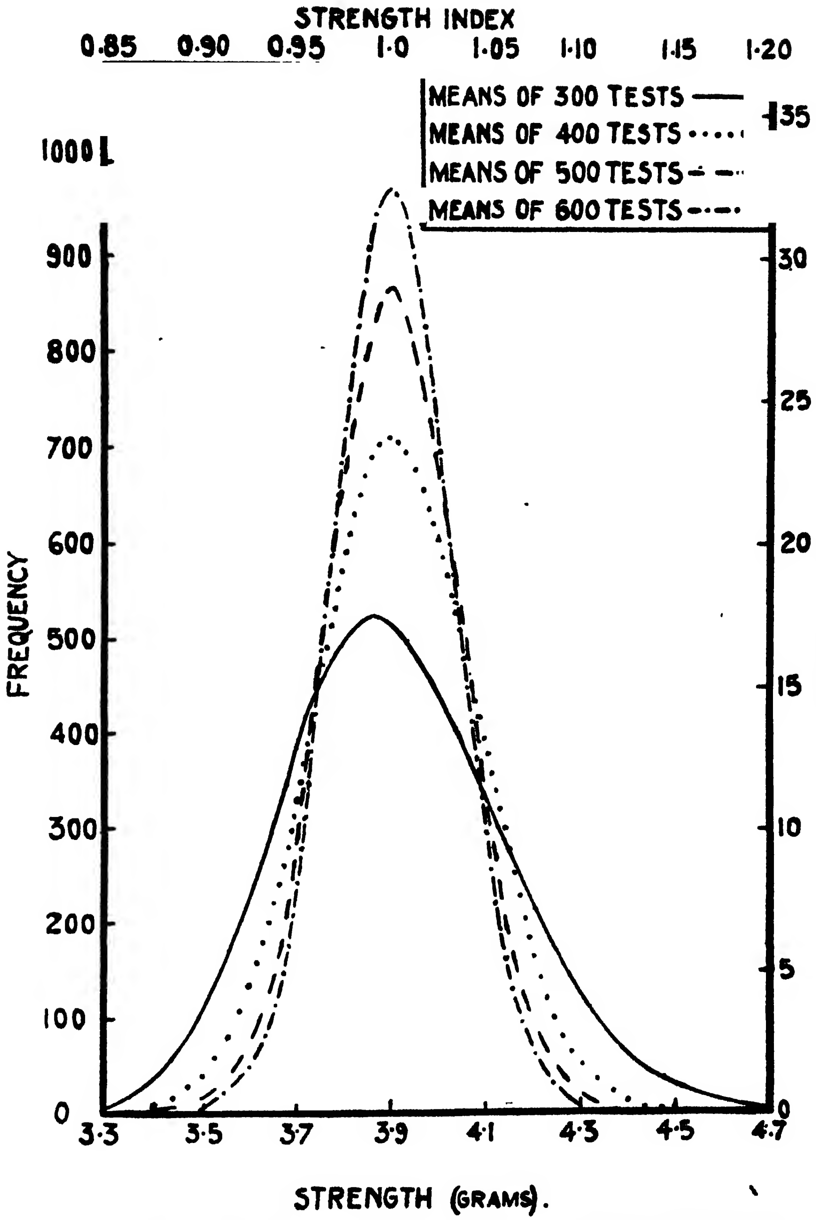

FIG. 2—Theoretical frequency-distribution of mean values of fibre-strength for Surat 1027 A.L.F.

If we regard odds of 19 to 1 as sufficiently accurate to mark the limits of differentiation, we obtain the following ranges for various subsamples—

Size of sample	300	400	500	600
Limits of range	3·45–4·35	3·57–4·23	3·63–4 17	3·66–4·14
Extent of range (gram)	0·90	0·66	0·54	0·48
Extent (% of arithmetic mean) ...	23·0	16·9	13·8	12·3

The ranges of the means of samples of different size may be seen from Figs. 1 and 2.

Fig. 1 shows the frequency-distribution of means of samples of size 300, 400, 500, and 600 respectively, while Fig. 2 shows the theoretical frequency-distributions of the same samples. Each curve represents the distribution of 3,000 mean values obtained by the moving-mean method. Along the top line are given the values of "strength index" obtained by dividing the corresponding values of strength shown along the x-axis, by 3·91 grams (the mean of the whole 3,000 tests). From Figs. 1 and 2 it will be seen that nearly all the means of samples of sizes 500 and 600 are included within the range of strength index 0·92–1·08, a total range of 15%, or 7½% on either side of the grand mean; hence 500 fibres constitute a satisfactory representative sample to this degree of accuracy. For 400 tests the corresponding total range is 17%. We can make use of these results to test whether a difference between two mean values is likely to be due to sampling or to some other cause. Thus, in "Technological Reports on Standard Indian Cottons," 1928,"[15] a table is given which includes the following figures for the percentage changes in fibre-strength in 1927–28 as compared with 1926–27—

Cotton	Fibre-strength
P. A. 4F	8
P. A. 285F	11
P. A. 289F	11
Mollisoni	5
Wagad 4	–43
Wagad 8	–34

The determinations of fibre-strength were made on 600 fibres of each sample (300 by each of two methods). Both the Wagad cottons have given much lower fibre-strengths in 1927–28, and the differences, 43% and 34%, are very much greater than the 15% regarded as the extreme limit which may be ascribed to the possible sampling error. We therefore conclude that both the Wagad cottons were really stronger in 1926–27 than in 1927–28. The differences for all the Punjab cottons fall within the limits of the possible sampling error, so that if each result were taken alone it would have to be regarded as possibly due to sampling fluctuations only.

(iii) *Application of Method (ii). Dispersion of values of small samples*—Table XII gives the values of the standard deviations for 30 sets each of 100, 200, 300, 400, 500, and 600 tests. The variation in the standard deviations for various subsamples decreases with increase in the size of the subsample; the ranges for 100 and 600 tests respectively are 1·330–3·001 and 2·093–2·659; the mean of the standard deviations gradually increases from 2·287 for 100 tests to 2·344 for 600 tests, and so approaches the standard deviation of the whole population, viz. 2·357, or 60·4% of the arithmetic mean. The values of the standard deviations for the different sizes of sample are as follows—

Size of sample	100	200	300	400	500	600
Mean standard deviation (gram)	2·287	2·317	2·332	2·337	2·343	2·344
S.D. of S.D.'s (gram)	0·322	0·256	0·218	0·186	0·163	0·151
S.D. (% of arithmetic mean) ...	8·24	6·54	5·59	4·75	4·18	3·85

It will be seen that the standard deviation of the standard deviations rapidly decreases with increase in the size of the sample, and for samples of size 500 is only 4·18% of the arithmetic mean.

(iv) *Application of Method (iii). Departure from fitness*—The 3,000 values for fibre-strength were divided into 30 successive and independent groups of 100 each, and the frequency-distribution obtained for each group, using 11 class-intervals each of 1 gram, except that strength-values of 10·95 grams or more were included in one class-interval. The 30 frequency-distributions

so obtained were then combined class by class, in groups 2, 3, 4, 5, and 6 respectively, by the moving-mean method, so as to give 30 frequency-distributions each for sets of 200, 300, 400, 500, and 600 tests. The different values of Δ and for d for the frequency-distributions of these samples are given in Tables XIII and XIV respectively.

From Tables XIII and XIV it will be seen that as the number of tests is increased, not only do the individual values of Δ and d rapidly decrease, but the variation among the different values of Δ and d respectively for each subsample also decreases. These facts are also clear from Fig. 3, in which the frequency-distributions of Δ are given for different sizes of sample. The

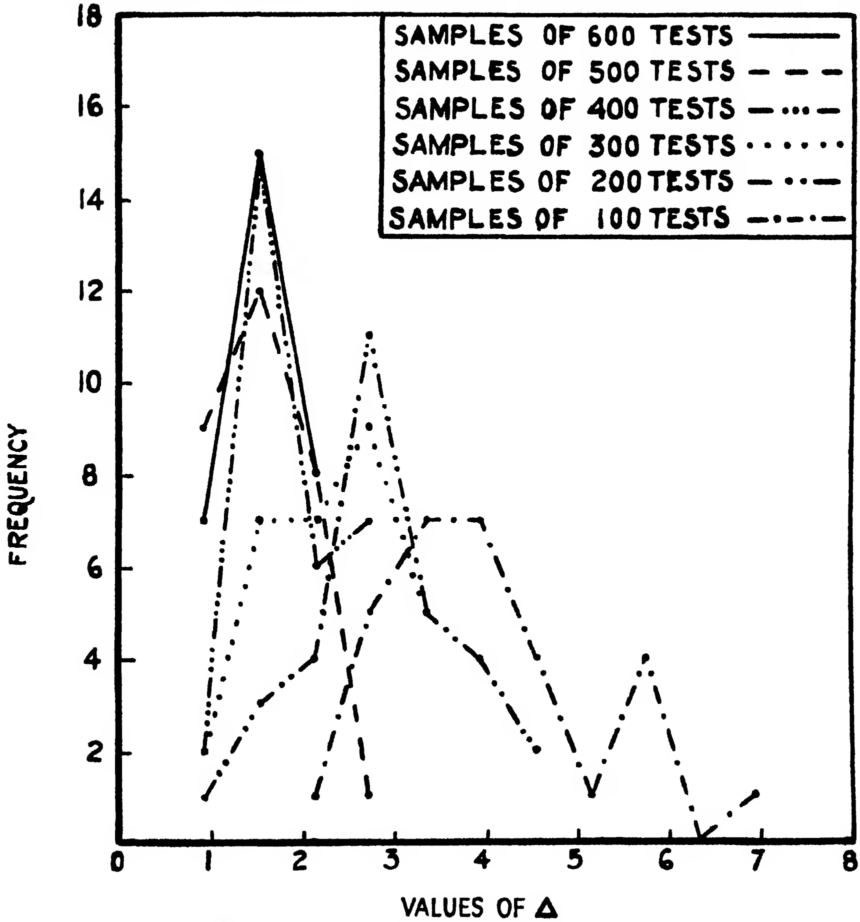

FIG. 3—Distribution of Δ's of fibre-strength for Surat 1027 A.L.F.

ranges of Δ for samples of 100 and 600 are 6·985–2·365 and 2·032–0·698 respectively. The following table shows the mean values of Δ and d for different sizes of subsamples—

Size of sample	100	200	300	400	500	600
Mean value of Δ	4·061	2·838	2·329	1·896	1·610	1·472
Maximum value of d ($= 10\Delta$) ...	40·6	28·4	23·3	19·0	16·1	14·7
Actual value of d	32·0	22·9	18·7	15·3	13·2	11·8

It will be observed that the actual value of d for any size of subsample is always less than that deduced from the value of Δ. Hence for samples of

size 500 the mean departure of fitness is only 1·61, and the mean (actual) deviation is only 13·2 per cent.

(5) Fibre-rigidity

Application of Method (i). Comparison of mean values of small and large samples—Table XV gives the 30 mean values each of sets of 100, 200, 300, 400, 500, 600, and 700 tests, the mean values for the multiples of 100 tests having been obtained by combining those for the sets of 100 tests by the moving-mean method. On examining column 2 we find that there is great variation among individual values, especially in the second 1,000 tests, i.e. in the region X–XX. This is due to the distribution of fibre-rigidity being extremely asymmetrical (J-shaped), and causing the mean value to be very sensitive to changes in individual values, for the inclusion of a few extremely high values may raise the mean value of a set of 100 by as much as 50%. Thus, Group XVII contains 12 fibres having individual values of fibre-rigidity 10×10^{-2} dyne-cm.^{2} and upwards. If these fibres are excluded, the mean is reduced from 3·66 to 2·27. On the other hand, some fibres tend to lower the mean value considerably; Group XIII contains no less than 33 fibres having values of fibre-rigidity $0{\cdot}1 \times 10^{-2}$ dyne-cm.^{2} or less; if these fibres are excluded, the mean value is raised by 50%—from 1·10 to 1·63. For these reasons the arithmetic mean, in the case of fibre-rigidity, cannot be regarded as a satisfactory single-valued representative of all the individual values of a sample. In spite of all the variations, however, we find that as the size of the sample is increased the mean values agree more and more among themselves—the ranges for 100 and 600 tests being 3·86–1·10, and 3·39-1·66 respectively.

Table X gives the frequency-distributions of 400 mean values for samples of sizes 300, 400, 500, and 600, obtained by the moving-mean method from the means of 10 test-values each—

Table X

Frequency-distributions of Mean Values of Sets of 300, 400, 500, and 600, obtained by the Moving-mean Method (Fibre-rigidity 4,000 Tests)

Fibre-rigidity 10^{-2}	300	400	500	600
1·20	1	—	—	—
1·30	8	1	—	
1·40	7	6	—	
1·50	7	7	8	
1·60	7	14	13	12
1·70	15	10	14	18
1·80	11	2	4	5
1·90	10	10	4	6
2·00	12	11	9	9
2·10	20	22	29	29
2·20	40	60	56	61
2·30	36	32	25	36
2·40	31	29	32	24
2·50	21	37	66	58
2·60	19	18	24	32
2·70	39	25	15	4
2·80	20	36	5	9
2·90	24	4	17	14
3·00	6	10	9	47
3·10	12	19	48	11
3·20	14	33	8	12
3·30	20	6	3	4
3·40	16	8	11	
3·50	4	—	—	
3·60	—	—	—	

In all cases the distributions of mean values are very irregular. The numbers of groups having values within the range 1·95–3·15 are shown below for different sizes of sample—

Size of sample	300	400	500	600
Number of values lying between 1·95 3·15—				
Actual	280	303	335	344
Percentage	70	76	84	86

The range 1·95–3·15 corresponds to 48% of the grand mean, so that even for a sample of size 500 the odds are only 5 to 1 that its mean value will lie within a range equal to 48% of the mean value.

We will now consider the distribution of mean values of samples of various size taken from the four series of 1,000 tests each.

The results for the first 1,000 fibres were first combined by the moving-mean method so as to give 1,000 mean values each for sets of 100, 200, 300, 400, and 500 tests. Next, the original 1,000 test values were divided into 100 successive and independent sets of 10 values each, and the 100 means obtained; these 100 means were then combined by the moving-mean method so as to give 100 mean values each for sets of 100, 200, 300, 400, and 500 tests. On comparing the frequency-distribution of the 1,000 means obtained from the original values for each size of sample with those of the 100 means for the same size of sample obtained after grouping the original values into sets of 10, it was found that the differences were very small indeed. Consequently in the case of the second, third, and fourth 1,000 test-values, the frequency-distributions have only been found for 100 means for each size of sample, obtained after grouping the original values into sets of 10. Table XI shows, for the separate sets of 1,000 tests, the frequency-distributions of the mean values for different sizes of sample—

Table XI

Frequency-distribution of Mean Values of Fibre-rigidity for Samples obtained by the Moving-mean Method from 1st, 2nd, 3rd, and 4th 1,000 Tests

Fibre-rigidity 10^{-2} Dynes cm²	First 1,000 Tests					Second 1,000 Tests			Third 1,000 Tests			Fourth 1,000 Tests		
	100	200	300	400	500	300	400	500	300	400	500	300	400	500
1·20	—	—	—	—	—	1	—	—	—	—		—		—
1·30		—		—	—	7	—				—	—	—	—
1·40	—	—	—	—	—	4	1	—	—	—	—	—	—	—
1·50	—	—		—	—	6	8	12	—	—	—	—	—	—
1·60	4	—	—	—	—	13	18	15	—	—		—	—	—
1·70	70			—	—	17	25	10	—	—		—	—	—
1·80	98	27	—	—	—	7	2	8	—	—	—	—	—	—
1·90	135	124	22	—	—	8	3	4		—			—	—
2·00	106	91	206	88	5	4	2	2	—	—	—	—	—	—
2·10	92	265	238	258	391	1	1	3	—	—	—	—	—	—
2·20	96	169	268	546	529	2	3	7	—	—	—	—	—	—
2·30	115	180	206	108	75	3	9	11		—	—	9	4	—
2·40	73	131	60	—	—	1	7	11	—	—	—	28	20	22
2·50	85	13	—	—	—	1	5	17	3	—	—	22	36	32
2·60	70	—	—	—	—	2	1	—	2	—	—	15	23	33
2·70	19	—	—	—	—	6	4	—	6	—	—	17	10	13
2·80	22	—	—	—	—	7	10	—	6	20	—	5	7	—
2·90	12	—	—	—	—	2	1	—	16	2	16	4	—	—
3·00	3	—	—	—	—	2	—	—	5	11	8	—	—	—
3·10	—	—	—	—	—	2	—	—	11	9	25	—	—	—
3·20	—	—	—	—	—	4	—	—	10	19	24	—	—	—
3·30	—	—	—	—	—	—	—	—	10	8	9	—	—	—
3·40	—	—	—	—	—	—	—	—	9	30	18	—	—	—
3·50	—	—	—	—	—	—	—	—	7	1	—	—	—	—
3·60	—	—	—	—	—	—	—	—	8	—	—	—	—	—
3·70	—	—	—	—	—	—	—	—	7	—	—	—	—	—

First 1,000 *Tests*—The results are more regular for the first sets of 1,000 tests than for any of the other three sets. The samples of size 100 show great variation; but samples of size 200 or more are comparatively symmetrical and concentrated round the mean. Out of the total number of 1,000 means, the numbers of means for different sizes of sample lying between certain limits are as follows—

Size of sample	100	200	300	400	500
Number of means between 2·05–2·25 ...	188	434	506	804	920
,, ,, , 1·95–2·35 ...	409	705	918	1,000	1,000

These figures show that for samples consisting of 400 and 500 fibres, the odds are 4·5 and 11·5 to 1 respectively that the means will not differ from the grand mean by more than about 5% on either side; for samples of 300, the odds are 11·5 to 1 that the mean will not differ by more than 9% on either side.

Second, third, and fourth 1,000 *Tests*—In the case of the second and third 1,000 tests, the distributions are very irregular for all sizes of sample, but in the fourth 1,000 tests, samples of 400 and 500 tests have given comparatively regular and symmetrical distributions. The numbers of groups lying within certain limits are as follows—

Set of Tests	Range	Size of Sample 300	Size of Sample 400	Size of Sample 500
		Number of means within range of Column 2		
Second 1,000 ...	1·45–2·55	63	83	100
Third 1,000 ..	2·85 3 45	61	79	100
Fourth 1,000 ..	2·35 2·75	82	91	100

In the case of the second 1,000 tests, the frequency-distributions of sizes 400 and 500 are actually U-shaped; as a result of the irregularity of these distributions only 63 and 83% respectively of samples of size 300 and 400 lie within 25% on either side of the grand mean. The irregularity of the third 1,000 tests is less marked than that of the second 1,000, and 61 and 79% respectively of its samples of size 300 and 400 lie within 10% on either side of the grand mean. The irregularity is still less in the case of the fourth 1,000 tests for which 82 and 91% respectively of samples of size 300 and 400 lie within 8% on either side of the grand mean.

The very conflicting results obtained for each separate set of 1,000 test-values serve to show that we cannot rely upon the result for any particular set of 1,000; and we must accordingly fall back upon the result already obtained for the whole 4,000 tests (page T42), recognising that owing to the extreme irregularity of the second and third 1,000 tests this result probably exaggerates the number of tests necessary in any given case.

(ii) *Application of Method* (*iii*). *Departure from fitness*—The 4,000 test-values for fibre-rigidity were divided into 40 successive and independent groups of 100 each, and the frequency-distribution obtained for each group, using the same class-interval (·004 dyne-cm.^{2}) and the same number of intervals (12) throughout; all the values above ·0475 dyne-cm.^{2} were included in one class-interval. The 40 frequency-distributions so obtained were then combined, class by class, by the moving-mean method so as to give 40 frequency-distributions each for sets of 200, 300, 400, 500, and 600 tests

respectively. The theoretical percentage frequency-distribution was calculated from Type I_J curve fitted to the observations. Table XVI gives the values of percentage deviation from fitness, *d*, for the frequency-distributions of samples of size 100, 200, 300, 400, 500, and 600. The individual values for each sample rapidly decrease with increase in the size of sample, the ranges for sets of 100 and 600 being 83·0–19·8 and 35·9–9·0 respectively. The mean value of *d* for the different subsamples are given below—

Size of sample	100	200	300	400	500	600
Mean value of *d*	37·8	30·4	26·0	22·6	20·3	18·8

With the increase in the size of the sample, the mean value of *d* rapidly decreases, and for samples of size 500 is 20·3 per cent.

IV—CONCLUSIONS

(1) Although the method of sampling adopted must usually be decided from certain general considerations, we have been able to show that the method of selecting individual fibres from a carefully-prepared sliver in which the fibres have been thoroughly mixed, shows a bias in favour of the selection of the longer fibres, and is therefore inferior to the method of selecting small bunches of fibres from different parts of the sliver, and testing every fibre in each bunch so selected.

(2) The mean value (i.e. the arithmetic mean) is usually satisfactory as a single value representing all the test-values obtained for a sample, but in the case of fibre-rigidity, for which the distribution is extremely asymmetrical, caution must be exercised in the use of the mean value as it is greatly affected by high individual values which are sometimes *ten times* as large as the arithmetic mean.

(3) In the case of fibre-length, fibre-width, and convolutions, which give nearly symmetrical frequency-distributions, the mean value and the probable error of a single observation are quite sufficient to indicate the composition of a sample. But in the case of fibre-strength, and more particularly in the case of fibre-rigidity, it is desirable to indicate the composition of a sample by means of the upper and lower quartiles, in addition to the mean value.

(4) The degree of reliability of small samples is indicated in the following table which shows the total range, expressed as a percentage of the mean, for which the odds are as indicated that the mean of a random sample of the given size will lie therein—

Range (% of mean) for which the Odds are shown that the Mean of a Random Sample will lie therein

Fibre-property	Odds	Size of Sample				
		200	300	400	500	600
Fibre-length ...	20 1	18	16	13	11	9
Fibre-width	20 1	4	2·7	2		
Convolutions ..	20 1	30	24	20	19	18
Fibre-strength..	20 1	40	23	17	15	13
Fibre-rigidity ...	5 1	—	60	55	48	44

Thus from col. 3, we see that the odds are 20:1 that the mean of a random sample of 200 fibres will lie within a range of 4% of the mean value of the

fibre-width; this range is equivalent to 2% on either side of the mean, seeing that the distribution of values of fibre-width is symmetrical.

(5) In the selection of a certain size of sample as representative, we are guided partly by the degree of reliability of the result for that size, and also by practical consideration of the difficulties of making a very large number of tests. Bearing both these points in mind we consider the following are the minimum numbers of tests which should be made in the determination of the several fibre-properties by the methods described in Part I[16]—

Fibre-property	Number of fibres for representative sample	Total range (% of mean) for which the odds are 20 to 1 that the random sample will lie therein
Fibre-length ...	500	11
Fibre-width ...	300	2·7
Convolutions ...	500	19
Fibre-strength ...	500	15
Fibre-rigidity ...	500	48 (odds 5:1)

(6) The results obtained in this investigation relate for the most part to Surat 1027 A.L.F. only. But, as remarked in Part I, this cotton was specially selected because previous tests had shown that its individual test-results displayed great variation. Consequently it may be inferred that the results obtained from any given number of tests of a certain property of another cotton will be at least as reliable as those obtained from the same number of tests of the same property of Surat 1027 A.L.F.

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25th September 1930

APPENDIX

TABLE I

Mean Values of Sets of 100, 200, 300, 400, 500, and 600 Tests—Fibre-length (3,000 Tests)

Group No.	100's	200's	300's	400's	500's	600's
I ...	2·29±·036	2·27±·029	2·30±·022	2·25±·019	2·21±·017	2·17±·015
II ...	2·24±·045	2·30±·028	2·23±·023	2·19±·019	2·15±·016	2·16±·015
III ...	2·37±·034	2·23±·026	2·17±·020	2·12±·017	2·14±·015	2·19±·014
IV ...	2·08±·039	2·07±·026	2·04±·019	2·08±·017	2·16±·015	2·20±·014
V ...	2·06±·033	2·02±·022	2·08±·018	2·18±·016	2·22±·014	2·28±·013
VI ...	1·98±·028	2·09±·022	2·22±·018	2·26±·016	2·32±·014	2·31±·013
VII ...	2·20±·034	2·34±·024	2·36±·019	2·41±·016	2·37±·015	2·36±·014
VIII ...	2·48±·032	2·44±·022	2·48±·018	2·41±·017	2·40±·015	2·36±·013
IX ...	2·39±·030	2·48±·021	2·39±·019	2·38±·017	2·34±·014	2·31±·013
X ...	2·56±·030	2·39±·024	2·37±·020	2·33±·016	2·29±·014	2·33±·013
XI ...	2·23±·038	2·28±·026	2·25±·019	2·22±·016	2·28±·015	2·31±·013
XII ...	2·32±·034	2·25±·022	2·22±·018	2·30±·015	2·32±·014	2·33±·012
XIII ...	2·19±·027	2·17±·020	2·29±·017	2·32±·015	2·34±·013	2·28±·012
XIV ...	2·14±·030	2·34±·022	2·37±·017	2·37±·015	2·29±·014	2·30±·012
XV ...	2·54±·032	2·38±·021	2·38±·017	2·28±·015	2·29±·013	2·31±·012
XVI ...	2·43±·027	2·41±·020	2·26±·017	2·28±·015	2·30±·013	2·28±·012
XVII ...	2·20±·030	2·19±·022	2·24±·017	2·27±·014	2·26±·013	2·25±·012
XVIII ...	1·98±·032	2·16±·021	2·23±·016	2·23±·014	2·22±·013	2·21±·012
XIX ...	2·34±·028	2·35±·018	2·31±·016	2·28±·014	2·25±·013	2·26±·012
XX ...	2·35±·024	2·29±·019	2·27±·016	2·23±·015	2·24±·014	2·22±·012
XXI ...	2·22±·030	2·21±·022	2·19±·018	2·21±·016	2·21±·014	2·24±·013
XXII ...	2·21±·031	2·17±·023	2·21±·017	2·19±·016	2·22±·014	2·22±·013
XXIII ...	2·13±·033	2·20±·023	2·18±·017	2·23±·016	2·22±·014	2·22±·013
XXIV ...	2·28±·033	2·20±·023	2·26±·018	2·25±·016	2·24±·015	2·22±·013
XXV ...	2·13±·031	2·25±·022	2·23±·018	2·23±·016	2·21±·014	2·22±·013
XXVI ..	2·37±·031	2·28±·021	2·26±·019	2·23±·016	2·24±·014	2·25±·013
XXVII ...	2·20±·029	2·21±·024	2·18±·018	2·21±·016	2·22±·015	2·23±·014
XXVIII ...	2·21±·038	2·18±·023	2·21±·019	2·23±·017	2·23±·016	2·25±·015
XXIX ...	2·14±·026	2·21±·021	2·23±·018	2·24±·018	2·26±·016	2·23±·015
XXX ...	2·27±·033	2·28±·024	2·27±·022	2·27±·019	2·25±·017	2·22±·015

TABLE II

Standard Deviations for Sets of 100, 200, 300, 400, 500, and 600 Tests—Fibre-length (3,000 Tests). Standard Deviation σ for 3,000 Tests – 0.4986)

Group No.	100's	200's	300's	400's	500's	600's
I ...	·5377	·6033	·5756	·5825	·5699	·5541
II ...	·6612	·5935	·5973	·5761	·5534	·5459
III ..	·5066	·5603	·5390	·5215	·5180	·5282
IV ...	·5715	·5324	·4989	·5035	·5249	·5186
V ...	·4883	·4564	·4781	·5106	·5039	·5095
VI ...	·4165	·4726	·5113	·4993	·5021	·5140
VII ...	·4981	·5116	·4892	·4847	·5064	·5081
VIII ..	·4752	·4625	·4594	·4987	·5023	·4935
IX ...	·4350	·4454	·5025	·5048	·4919	·4893
X ...	·4387	·5316	·5265	·5040	·4974	·5021
XI ...	·5631	·5392	·5007	·4877	·5013	·4890
XII ...	·5087	·4645	·4605	·4834	·4710	·4680
XIII ...	·4032	·4231	·4751	·4609	·4592	·4816
XIV ...	·4388	·4980	·4705	·4642	·4935	·4810
XV ...	·4697	·4402	·4451	·4981	·4820	·4639
XVI ...	·3992	·4243	·4901	·4714	·4501	·4581
XVII ..	·4459	·5088	·4845	·4539	·4620	·4606
XVIII ...	·4764	·4809	·4445	·4565	·4558	·4605
XIX ...	·4099	·3846	·4253	·4329	·4455	·4529
XX ...	·3494	·4278	·4362	·4493	·4688	·4592
XXI ...	·4918	·4730	·4768	·4809	·4774	·4792
XXII ...	·4516	·4679	·4769	·4734	·4764	·4690
XXIII ...	·4783	·4887	·4798	·4717	·4722	·4890
XXIV ...	·4854	·4781	·4786	·4675	·4889	·4739
XXV ...	·4567	·4746	·4606	·4890	·4705	·4735
XXVI ...	·4583	·4531	·4967	·4716	·4746	·4860
XXVII ...	·4281	·5017	·4763	·4721	·4871	·5204
XXVIII ...	·5563	·4831	·4856	·5004	·5366	·5347
XXIX ...	·3803	·4408	·4767	·5291	·5278	·5397
XXX ...	·4846	·5024	·5667	·5546	·5644	·5571
Mean S.D....	·4722	·4841	·4895	·4918	·4945	·4954
S.D. of S.D.'s	·06267	·04854	·03855	·03412	·03189	·03008

TABLE III

Values of Total Percentage Deviation from Fitness (d) for Sets of 100, 200, 300, 400, and 500 Tests—Fibre-length (3,000 Tests)

Group No.	100	200	300	400	500
I	13·4	22·0	25·0	24·1	18·2
II	39·8	33·2	29·5	21·6	21·0
III	36·8	29·0	18·9	19·9	17·6
IV	32·8	26·6	29·3	24·3	15·4
V	31·2	38·2	28·4	15·2	8·8
VI	45·2	27·6	11·6	8·7	14·0
VII	17·4	15·0	20·2	27·5	26·0
VIII	39·0	35·2	39·6	34·8	29·8
IX	33·8	40·6	33·9	28·1	19·8
X	49·6	38·8	29·5	18·1	14·2
XI	50·0	24·4	13·7	15·6	13·8
XII	14·6	10·2	11·3	9·6	13·8
XIII	23·8	19·6	7·8	14·6	18·2
XIV	24·0	19·0	21·6	24·4	13·6
XV	49·7	42·0	38·4	20·6	21·2
XVI	35·4	34·4	12·8	16·0	17·6
XVII	37·4	17·4	15·7	16·6	11·2
XVIII	43·6	26·4	20·1	15·2	13·6
XIX	30·4	30·4	17·0	13·2	11·0
XX	31·0	13·8	8·2	10·6	6·2
XXI	19·6	11·2	14·8	10·4	13·4
XXII	13·6	15·2	9·7	14·0	11·0
XXIII	25·2	12·0	13·4	11·2	9·0
XXIV	22·4	18·2	15·4	10·8	9·8
XXV	32·2	16·2	10·2	9·4	13·2
XXVI	23·0	12·0	12·2	12·6	12·0
XXVII	26·2	19·8	19·6	14·8	13·2
XXVIII	21·2	21·4	15·5	13·0	14·4
XXIX	35·8	16·6	12·1	13·0	13·4
XXX	20·8	14·6	17·2	22·0	21·8
Mean ...	30·6	23·4	19·1	17·0	15·2

TABLE IV

Values of Coefficient of Fitness Δ for Sets of 100, 200, 300, 400, and 500 Tests—Fibre-length (3,000 Tests)

Group No.	100's	200's	300's	400's	500's
I	3·53	4·29	3·08	3·87	3·46
II	7·52	4·24	4·90	4·01	4·00
III	4·24	4·24	3·53	3·91	3·30
IV	8·71	5·54	5·55	4·32	2·98
V	6·01	6·29	4·54	2·75	1·79
VI	6·81	4·08	1·83	1·19	1·64
VII	2·98	2·09	2·22	3·02	2·84
VIII	5·04	3·97	4·53	3·79	3·28
IX	4·27	4·58	3·84	3·08	2·26
X	6·19	4·10	3·19	2·14	2·37
XI	5·79	2·90	1·91	2·43	1·76
XII	2·35	1·97	2·40	1·68	1·95
XIII	3·10	3·05	1·49	1·96	2·21
XIV	3·79	2·55	2·82	2·97	1·84
XV	6·83	5·22	4·52	2·74	2·55
XVI	4·28	3·88	2·13	2·23	2·05
XVII	4·45	2·96	2·39	2·26	1·68
XVIII	6·66	3·43	2·63	1·97	1·76
XIX	3·88	3·65	2·38	2·02	1·80
XX	3·94	2·26	1·77	1·73	1·47
XXI	2·82	1·90	2·08	1·76	2·04
XXII	2·28	2·31	1·83	2·19	1·68
XXIII	3·38	1·89	2·28	1·61	1·65
XXIV	2·87	2·50	2·20	1·88	1·78
XXV	4·18	2·19	2·04	1·99	2·06
XXVI	3·62	2·11	1·88	2·10	2·00
XXVII	3·60	3·08	2·94	2·43	2·15
XXVIII	4·21	3·24	2·48	2·26	2·19
XXIX	4·78	2·84	2·07	1·73	1·60
XXX	3·22	2·29	2·66	2·64	3·15
Mean ...	4·51	3·32	2·80	2·49	2·24

TABLE V

Mean Values of Sets of 100, 200, 300, 400, and 500 Tests—Fibre-width (3,000 Tests)

Group No.	100's	200's	300's	400's	500's
I	178·5 ± 1·36	174·4 ± 1·04	176·5 ± 0·82	174·9 ± 0·69	173·8 ± 0·61
II	170·4 ± 1·58	175·6 ± 1·03	173·8 ± 0·80	172·6 ± 0·68	172·6 ± 0·60
III	180·7 ± 1·30	175·4 ± 0·91	173·3 ± 0·73	173·1 ± 0·63	173·1 ± 0·55
IV	170·2 ± 1·27	169·7 ± 0·88	170·1 ± 0·72	171·2 ± 0·61	171·7 ± 0·53
V	169·2 ± 1·21	170·8 ± 0·87	171·5 ± 0·70	172·0 ± 0·59	172·4 ± 0·51
VI	172·4 ± 1·26	172·7 ± 0·85	173·0 ± 0·67	173·3 ± 0·56	173·1 ± 0·50
VII	173·1 ± 1·14	173·3 ± 0·79	173·6 ± 0·62	173·2 ± 0·53	175·5 ± 0·52
VIII	173·5 ± 1·08	173·8 ± 0·73	173·3 ± 0·60	176·1 ± 0·58	178·4 ± 0·53
IX	174·1 ± 1·00	173·2 ± 0·72	176·9 ± 0·68	179·6 ± 0·61	181·3 ± 0·57
X	172·3 ± 1·05	178·3 ± 0·90	181·4 ± 0·74	183·1 ± 0·67	184·3 ± 0·60
XI	184·4 ± 1·46	186·0 ± 0·98	186·8 ± 0·82	187·3 ± 0·70	186·3 ± 0·64
XII	187·5 ± 1·31	187·9 ± 0·99	188·3 ± 0·79	186·9 ± 0·71	186·4 ± 0·61
XIII	188·4 ± 1·47	188·7 ± 0·99	186·6 ± 0·84	186·1 ± 0·69	185·9 ± 0·60
XIV	189·1 ± 1·34	185·7 ± 1·03	185·3 ± 0·78	185·2 ± 0·66	185·6 ± 0·57
XV	182·4 ± 1·56	183·4 ± 0·97	184·0 ± 0·76	184·8 ± 0·63	185·1 ± 0·55
XVI	184·4 ± 1·15	184·8 ± 0·83	185·5 ± 0·66	185·8 ± 0·57	185·2 ± 0·52
XVII	185·1 ± 1·18	186·1 ± 0·80	186·3 ± 0·65	185·4 ± 0·58	184·6 ± 0·53
XVIII	187·1 ± 1·07	186·9 ± 0·78	185·6 ± 0·66	184·5 ± 0·60	182·5 ± 0·52
XIX	186·7 ± 1·14	184·8 ± 0·84	183·6 ± 0·71	181·1 ± 0·59	180·1 ± 0·52
XX	182·9 ± 1·23	182·1 ± 0·90	179·2 ± 0·68	178·4 ± 0·58	178·2 ± 0·54
XXI	181·3 ± 1·31	177·3 ± 0·82	176·9 ± 0·65	177·1 ± 0·60	177·3 ± 0·54
XXII	173·4 ± 0·99	174·7 ± 0·73	175·7 ± 0·67	176·3 ± 0·59	176·6 ± 0·54
XXIII	176·1 ± 1·06	176·8 ± 0·88	177·2 ± 0·71	177·3 ± 0·62	176·9 ± 0·55
XXIV	177·6 ± 1·41	177·8 ± 0·92	177·8 ± 0·75	177·1 ± 0·63	178·7 ± 0·57
XXV	178·1 ± 1·18	177·9 ± 0·88	176·9 ± 0·70	179·0 ± 0·62	181·9 ± 0·57
XXVI	177·7 ± 1·30	176·4 ± 0·88	179·3 ± 0·73	182·9 ± 0·64	183·5 ± 0·59
XXVII	175·1 ± 1·17	180·1 ± 0·88	184·7 ± 0·74	185·0 ± 0·67	183·7 ± 0·60
XXVIII	185·1 ± 1·32	189·5 ± 0·94	188·3 ± 0·80	185·8 ± 0·69	182·7 ± 0·64
XXIX	193·8 ± 1·35	189·9 ± 1·00	185·3 ± 0·80	181·6 ± 0·72	181·4 ± 0·63
XXX	186·0 ± 1·47	182·2 ± 1·00	178·3 ± 0·85	178·9 ± 0·72	177·1 ± 0·63

TABLE VI

Standard Deviations for Sets of 100, 200, 300, 400, and 500 Tests—Fibre-width (3,000 Tests). (Standard Deviation σ for 3,000 Tests - 19·92)

Group No.	100	200	300	400	500
I	20·16	22·14	21·44	21·01	20·58
II	23·26	21·96	21·14	20·50	20·15
III	19·32	19·81	19·46	19·27	18·83
IV	18·88	18·47	18·57	18·12	17·81
V	18·01	18·41	17·97	17·51	17·02
VI	18·65	17·86	17·23	16·65	16·30
VII	16·96	16·46	15·92	15·66	17·60
VIII	15·95	15·36	15·20	17·48	18·83
IX	14·75	14·81	18·17	19·28	20·35
X	15·55	19·51	20·23	21·12	20·99
XI	21·65	20·95	21·58	21·18	21·09
XII	20·06	21·41	20·89	21·64	20·84
XIII	22·67	21·30	22·15	21·03	20·99
XIV	19·84	21·78	20·34	19·68	18·98
XV	23·09	20·33	19·46	18·65	18·20
XVI	17·07	17·31	16·84	16·68	17·00
XVII	17·55	16·70	16·51	16·97	17·57
XVIII	15·91	15·93	16·81	17·58	17·63
XIX	16·11	17·23	18·08	17·89	16·88
XX	18·09	18·97	18·01	17·54	18·27
XXI	19·38	17·64	17·04	18·09	18·06
XXII	14·68	15·29	17·42	17·57	17·96
XXIII	15·76	18·53	18·18	17·61	18·40
XXIV	20·84	19·46	19·45	18·98	19·44
XXV	17·91	18·67	18·29	18·95	20·09
XXVI	19·31	18·46	19·40	20·49	20·66
XXVII	17·37	19·15	20·55	20·71	20·76
XXVIII	19·54	20·41	20·71	21·00	22·33
XXIX	20·44	21·12	21·46	22·93	22·26
XXX	21·15	21·00	22·48	21·76	21·50
Mean S.D.	18·664	18·881	19·033	19·118	19·249
S.D. of S.D.'s ...	2·365	2·084	1·930	1·837	1·685

TABLE VII

Values of Total Percentage Deviation from Fitness (*d*) for Sets of 100, 200, 300, 400, and 500 Tests—Fibre-width (Second 1,000 Tests)

Group No.	100's	200's	300's	400's	500's
I	24·7	13·0	15·8	13·4	9·2
II	22·6	22·8	18·0	11·9	10·6
III	31·6	20·0	11·7	10·6	9·8
IV	35·8	10·6	5·5	8·1	8·8
V	36·0	20·4	18·2	15·4	13·0
VI	17·6	15·6	15·0	16·6	14·0
VII	23·6	17·4	17·8	14·4	11·6
VIII	29·4	26·2	20·9	17·1	12·8
IX	26·0	18·5	17·2	12·2	11·4
X	19·4	18·2	11·0	11·2	10·0
Mean ...	26·7	18·3	15·1	13·1	11·1

TABLE VIII

Mean Values of Sets of 100, 200, 300, 400, 500, and 600 Tests—Convolutions (3,000 Tests)

Group No.	100's	200's	300's	400's	500's	600's
I ...	96·2±1·95	94·7±1·45	94·8±1·14	92·4±0·97	91·0±0·86	89·6±0·76
II ...	93·1±2·15	94·2±1·41	91·2±1·12	89·7±0·96	88·3±0·82	87·8±0·76
III ...	95·2±1·81	90·2±1·30	85·5±1·05	87·1±0·88	86·7±0·80	88·7±0·73
IV ...	85·2±1·86	85·2±1·29	84·4±1·00	84·6±0·89	87·3±0·80	87·8±0·74
V ...	85·1±1·79	84·1±1·18	84·4±1·02	87·9±0·89	88·3±0·80	89·9±0·73
VI ...	83·0±1·54	84·1±1·24	88·8±1·02	89·2±0·90	90·8±0·80	90·5±0·75
VII ...	85·2±1·93	91·7±1·32	91·2±1·08	92·8±0·93	92·0±0·84	94·0±0·80
VIII ...	98·2±1·80	94·2±1·30	95·3±1·06	93·7±0·94	95·7±0·88	95·8±0·80
IX ...	90·2±1·86	93·8±1·31	92·2±1·10	95·1±1·01	95·4±0·89	94·7±0·82
X ...	97·4±1·84	93·2±1·36	96·7±1·19	96·7±1·02	95·6±0·91	97·7±0·84
XI ...	88·9±2·00	96·4±1·54	96·4±1·21	95·1±1·05	97·8±0·94	98·8±0·86
XII ...	103·8±2·33	100·2±1·51	97·2±1·23	100·0±1·07	100·7±0·95	99·5±0·87
XIII ...	96·5±1·91	93·9±1·43	98·8±1·19	100·0±1·04	98·6±0·94	94·3±0·84
XIV ...	91·2±2·11	99·9±1·51	101·1±1·23	99·2±1·07	93·8±0·93	92·0±0·84
XV ...	108·6±2·15	106·1±1·51	101·8±1·24	94·5±1·04	92·1±0·92	91·5±0·84
XVI ...	103·5±2·11	98·4±1·52	89·8±1·19	88·0±1·01	88·1±0·91	87·0±0·82
XVII ...	93·3±2·18	82·9±1·44	82·8±1·15	84·3±1·01	83·6±0·89	84·5±0·84
XVIII ...	72·5±1·87	77·6±1·35	81·3±1·12	81·2±0·98	82·8±0·91	82·7±0·82
XIX ...	82·6±1·93	85·7±1·41	84·1±1·14	85·4±1·03	84·8±0·91	85·2±0·84
XX ...	88·7±2·04	84·9±1·41	86·3±1·22	85·3±1·04	85·7±0·93	86·6±0·87
XXI ...	81·1±1·95	85·1±1·51	84·2±1·20	85·0±1·04	86·2±0·95	87·6±0·88
XXII ...	89·0±2·31	85·7±1·52	86·3±1·23	87·4±1·09	88·9±0·98	88·0±0·89
XXIII ...	82·4±1·96	84·9±1·44	86·9±1·23	88·9±1·08	87·8±0·96	86·7±0·88
XXIV ...	87·4±2·10	89·2±1·57	91·0±1·29	89·2±1·09	87·6±0·98	85·4±0·86
XXV ...	90·9±2·32	82·9±1·62	89·8±1·28	87·6±1·10	85·0±0·95	83·4±0·85
XXVI ...	94·8±2·27	89·3±1·53	86·5±1·25	83·5±1·03	81·9±0·91	84·3±0·83
XXVII ...	83·7±2·04	82·4±1·49	79·7±1·15	78·6±0·99	82·1±0·88	84·0±0·82
XXVIII ...	81·1±2·18	77·8±1·40	76·9±1·12	81·8±0·98	84·0±0·89	85·9±0·80
XXIX ...	74·4±1·74	74·9±1·29	82·0±1·08	84·8±0·97	86·8±0·86	86·8±0·78
XXX ...	75·3±1·90	85·8±1·36	88·2±1·16	90·0±0·98	89·0±0·87	88·4±0·78

TABLE IX

Standard Deviations for Sets of 100, 200, 300, 400, and 500 Tests—Convolutions (3,000 Tests). (Standard Deviation σ for 3,000 Tests=30·90)

Group No.	100's	200's	300's	400's	500's
I	28·95	30·51	29·36	29·23	28·85
II	31·92	29·54	29·22	28·67	27·75
III	26·90	27·81	27·23	26·46	26·92
IV	27·63	27·07	25·76	26·50	27·10
V	26·50	24·77	26·14	26·99	27·09
VI	22·86	25·93	27·03	26·72	27·43
VII	28·62	28·53	28·22	28·08	28·44
VIII	26·74	27·45	27·44	28·14	29·82
IX	27·55	27·67	28·43	30·51	30·09
X	27·30	28·81	31·26	30·54	30·77
XI	29·62	33·05	31·54	31·56	31·59
XII	34·57	31·81	31·91	32·77	32·10
XIII	28·31	29·95	31·37	31·40	31·70
XIV	31·27	32·73	32·28	32·46	33·32
XV	31·83	31·64	32·43	33·78	33·16
XVI	31·24	32·19	33·10	32·19	31·80
XVII	32·32	31·86	30·82	30·77	30·44
XVIII	27·73	28·65	29·63	29·29	30·65
XIX	28·65	29·58	29·44	30·80	30·48
XX	30·19	29·81	31·44	30·89	30·97
XXI	28·93	31·98	31·05	31·12	31·89
XXII	34·31	31·95	31·70	32·47	32·58
XXIII	29·03	30·23	31·81	32·47	32·10
XXIV	31·17	32·89	33·27	32·68	32·77
XXV	34·43	34·13	33·15	33·14	32·26
XXVI	33·71	32·48	32·64	31·52	31·05
XXVII	30·19	31·29	29·82	29·49	30·22
XXVIII	32·29	29·43	29·06	30·20	30·89
XXIX	25·83	27·06	29·48	30·48	30·10
XXX	28·23	30·44	31·13	30·28	29·75
Mean S.D.	29·627	30·041	30·239	30·387	30·469
S.D. of S.D.'s ...	2·762	2·283	2·094	2·027	1·836

TABLE X

Values of Total Percentage Deviation from Fitness (*d*) for Sets of 100, 200, 300, 400, and 500 Tests—Convolutions (3,000 Tests)

Group No.	100's	200's	300's	400's	500's
I	15·2	10·2	8·9	7·3	12·0
II	16·8	7·4	10·5	15·3	18·9
III	23·4	15·4	21·7	27·7	25·0
IV	33·8	32·8	29·9	27·9	19·8
V	39·8	28·9	35·1	23·8	20·6
VI	46·4	40·4	22·1	19·7	16·2
VII	37·4	19·2	13·8	10·0	10·2
VIII	20·6	11·6	11·4	11·6	10·4
IX	17·6	13·8	12·3	13·0	9·1
X	17·0	11·6	15·9	11·3	11·8
XI	27·6	22·4	14·0	14·5	16·2
XII	46·0	27·2	22·1	22·6	19·2
XIII	17·7	13·2	15·6	15·3	14·0
XIV	24·8	23·4	23·0	19·7	15·4
XV	27·7	31·6	23·2	15·1	14·9
XVI	30·6	16·4	17·1	19·3	18·4
XVII	17·4	33·8	30·2	26·4	30·4
XVIII	60·0	51·4	29·5	35·8	34·0
XIX	31·2	20·8	28·2	27·8	28·0
XX	16·8	29·3	28·7	28·8	30·0
XXI	42·8	34·8	32·8	33·3	32·6
XXII	30·6	29·8	30·2	28·9	23·8
XXIII	41·8	32·8	29·5	23·2	23·8
XXIV	36·3	33·6	22·9	23·2	27·5
XXV	31·6	22·4	20·1	25·6	30·4
XXVI	33·4	30·4	29·7	31·2	36·4
XXVII	34·8	36·8	42·1	45·3	34·8
XXVIII	45·2	48·3	46·7	35·9	29·6
XXIX	52·8	53·8	33·3	25·9	21·8
XXX	54·8	26·4	19·0	15·2	15·0
Mean ...	32·4	27·0	24·0	22·7	21·7

TABLE XI

Mean Values of Sets of 100, 200, 300, 400, 500, and 600 Tests—Fibre-strength (3,000 Tests)

Group No.	100's	200's	300's	400's	500's	600's
I ...	3·63±·188	3·525±·124	3·83±·101	3·80±·083	3·81±·072	3·83±·066
II ...	3·42±·162	3·930±·118	3·85±·092	3·86±·076	3·87±·070	3·89±·064
III ...	4·44±·174	4·070±·113	4·06±·086	3·98±·078	3·98±·070	3·93±·063
IV ...	3·70±·140	3·790±·097	3·83±·087	3·87±·076	3·83±·067	3·80±·057
V ...	3·88±·136	3·900±·110	3·93±·090	3·86±·075	3·82±·062	3·86±·050
VI ...	3·92±·175	3·955±·117	3·86±·092	3·80±·070	3·86±·062	3·87±·058
VII ...	3·99±·158	3·825±·106	3·76±·074	3·84±·065	3·86±·060	3·81±·056
VIII ...	3·66±·143	3·600±·080	3·76±·067	3·81±·063	3·75±·059	3·63±·054
IX ...	3·64±·085	3·860±·078	3·89±·073	3·80±·065	3·65±·060	3·73±·057
X ...	4·08±·135	4·015±·104	3·85±·084	3·65±·072	3·75±·067	3·70±·060
XI ...	3·95±·151	3·735±·106	3·50±·085	3·67±·076	3·63±·068	3·82±·065
XII ...	3·52±·150	3·280±·103	3·57±·088	3·55±·076	3·80±·072	3·98±·068
XIII ...	3·04±·143	3·595±·112	3·56±·088	3·87±·087	4·08±·076	3·99±·066
XIV ...	4·15±·164	3·815±·110	4·14±·099	4·34±·088	4·18±·074	4·03±·066
XV ...	3·48±·149	4·145±·127	4·40±·104	4·16±·083	3·99±·072	3·98±·064
XVI ...	4·81±·202	4·865±·139	4·42±·099	4·14±·082	4·10±·071	4·19±·066
XVII ...	4·92±·191	4·225±·115	3·91±·087	3·93±·074	4·07±·069	3·98±·061
XVIII ...	3·53±·124	3·410±·093	3·59±·077	3·86±·072	3·80±·063	3·79±·058
XIX ...	3·29±·140	3·625±·098	3·97±·087	3·86±·072	3·84±·065	3·82±·061
XX ...	3·96±·136	4·315±·111	4·05±·084	3·98±·074	3·93±·067	3·95±·061
XXI ...	4·67±·177	4·100±·108	3·99±·087	3·92±·077	3·95±·069	4·04±·064
XXII ...	3·53±·122	4·645±·097	3·67±·085	3·77±·074	3·91±·068	3·86±·062
XXIII ...	3·76±·155	3·745±·112	3·85±·090	4·01±·079	3·93±·070	3·89±·061
XXIV ...	3·73±·164	3·890±·111	4·09±·093	3·97±·079	3·92±·069	3·91±·064
XXV ...	4·05±·151	4·275±·112	4·05±·090	3·97±·076	3·94±·070	4·09±·064
XXVI ...	4·50±·166	4·055±·112	3·95±·088	3·92±·079	4·10±·070	4·02±·066
XXVII ...	3·61±·152	3·670±·103	3·72±·089	4·00±·078	3·93±·072	3·85±·064
XXVIII ...	3·73±·140	3·775±·110	4·13±·090	4·00±·082	3·82±·071	4·01±·064
XXIX ...	3·82±·171	4·330±·118	4·10±·099	3·65±·078	4·07±·070	3·89±·063
XXX ...	4·84±·157	4·235±·125	3·66±·091	4·07±·079	3·95±·069	3·91±·060

TABLE XII

Standard Deviations for Sets of 100, 200, 300, 400, 500, and 600 Tests—Fibre-strength (3,000 Tests). (Standard Deviation σ for 3,000 Tests = 2·357)

Group No.	100's	200's	300's	400's	500's	600's
I ...	2·879	2·673	2·544	2·460	2·411	2·438
II ...	2·314	2·354	2·302	2·277	2·338	2·319
III ...	2·259	2·272	2·249	2·333	2·310	2·277
IV ..	2·190	2·197	2·327	2·273	2·261	2·134
V ...	2·256	2·390	2·334	2·278	2·123	2·093
VI ...	2·566	2·398	2·303	2·103	2·071	2·107
VII ...	2·216	2·159	1·923	1·927	2·003	2·113
VIII ...	2·091	1·748	1·817	1·905	2·090	2·120
IX ...	1·320	1·663	1·892	2·098	2·125	2·185
X ...	1·919	2·110	2·286	2·283	2·319	2·297
XI ...	2·280	2·439	2·371	2·400	2·357	2·515
XII ...	2·574	2·386	2·432	2·369	2·559	2·659
XIII ...	2·146	2·358	2·297	2·552	2·667	2·574
XIV ...	2·417	2·322	2·611	2·717	2·607	2·547
XV ...	2·168	2·703	2·807	2·652	2·571	2·491
XVI ...	3·001	2·965	2·751	2·644	2·536	2·540
XVII ...	2·927	2·599	2·477	2·375	2·420	2·340
XVIII ...	1·994	2·040	2·054	2·225	2·154	2·192
XIX ...	2·076	2·083	2·287	2·188	2·227	2·249
XX ...	2·099	2·316	2·194	2·243	2·268	2·261
XXI ...	2·514	2·266	2·306	2·322	2·302	2·345
XXII ...	1·843	2·119	2·201	2·212	2·290	2·295
XXIII ...	2·374	2·366	2·322	2·383	2·373	2·340
XXIV ...	2·357	2·295	2·382	2·373	2·333	2·342
XXV ...	2·222	2·324	2·374	2·325	2·338	2·348
XXVI ...	2·503	2·446	2·358	2·366	2·372	2·470
XXVII ...	2·307	2·232	2·286	2·328	2·452	2·435
XXVIII ...	2·153	2·273	2·322	2·476	2·458	2·440
XXIX ...	2·386	2·375	2·574	2·526	2·490	2·445
XXX ...	2·256	2·653	2·570	2·513	2·456	2·415
Mean S.D....	2·2869	2·3175	2·3318	2·3375	2·3427	2·3442
S.D. of S.D.'s	·3222	·2558	·2185	·1859	·1633	·1507

TABLE XIII

Values of Coefficient of Fitness Δ for Sets of 100, 200, 300, 400, 500, and 600 Tests—Fibre-strength (3,000 Tests)

Group No.	100's	200's	300's	400's	500's	600's
I ...	5·655	2·745	2·702	1·738	1·360	1·415
II ...	3·950	2·526	1·539	1·308	1·158	1·260
III ...	3·865	1·694	1·797	1·463	1·513	1·281
IV ...	2·948	2·618	2·117	1·871	1·607	1·772
V ...	3·401	1·912	1·853	1·539	1·861	1·852
VI ...	3·411	1·670	1·490	1·683	1·822	1·811
VII ...	2·932	2·293	2·837	2·618	2·274	1·889
VIII ...	3·258	3·861	3·267	2·855	2·665	1·996
IX ...	6·985	4·358	3·455	3·030	2·192	1·907
X ...	3·572	3·508	2·946	2·404	2·216	2·024
XI ...	4·196	3·665	3·333	2·593	2·419	2·032
XII ...	4·414	4·113	2·919	2·672	2·238	1·877
XIII ...	5·677	3·384	3·118	2·641	2·322	1·921
XIV ...	3·463	2·509	2·598	2·555	2·000	1·680
XV ...	2·957	3·194	2·880	2·221	1·761	1·229
XVI ...	5·516	4·714	3·162	2·110	1·517	1·649
XVII ...	5·415	3·081	2·249	1·714	1·473	1·270
XVIII ...	3·848	3·162	2·274	1·625	1·153	1·315
XIX ...	4·254	2·664	2·114	1·240	1·300	0·841
XX ...	3·637	2·948	1·694	1·402	0·940	0·930
XXI ...	4·117	1·571	1·732	1·483	1·102	1·319
XXII ...	3·738	2·200	1·841	1·556	1·504	1·142
XXIII ...	4·532	2·522	1·360	1 513	0·953	0·767
XXIV ...	4·057	2·876	2·608	1·664	1·014	1·292
XXV ...	2·734	2·687	1·233	0·642	1·005	1·513
XXVI ...	3.601	1·136	0·884	1·327	1·673	1·628
XXVII ...	2·956	1·861	2·007	1·715	1·753	1·091
XXVIII ...	2·365	2·685	2 540	2·348	1·389	1·302
XXIX ...	4·379	3·974	2·945	2·046	1·174	0·698
XXX ...	5·989	3·021	2·400	1 315	0 946	1·455

TABLE XIV

Values of Total Percentage Deviation from Fitness for Sets of 100, 200, 300, 400, 500, and 600 Tests—Fibre-strength (3,000 Tests)

Group No.	100's	200's	300's	400's	500's	600's
I ...	38·1	25·2	19·0	15·0	12·0	12·2
II ...	32·4	18·8	12 5	10·7	10·4	10·9
III ...	33·8	15·0	13·6	13·2	13·4	12·1
IV ...	24·4	19·7	17 0	16·0	14·4	13·3
V ...	25·2	14·4	16·8	13·9	14·2	15·5
VI ...	29·8	14·6	12·8	13·7	16·2	15·5
VII ...	22·8	17·1	23·6	21·6	19·8	14·3
VIII ...	20·0	33·4	27·5	24·0	17·4	13·1
IX ...	64·2	35·4	27·4	18·3	14·0	13·3
X ...	29·5	30·0	24·5	21·0	19·6	17·6
XI ...	33·6	29·8	26·8	23·9	20·6	17·4
XII ...	39·8	35·4	23·8	20 4	17·0	13·4
XIII ...	39·0	22·8	21·6	17·9	16·0	14·2
XIV ...	25·0	18·6	18·9	20·2	17·0	14·0
XV ...	20·8	20·8	21·7	18·0	14·4	10·2
XVI ...	41·8	33·0	23·7	15·8	11·6	10·1
XVII ...	41·2	26·6	19·2	12·1	12·4	8·6
XVIII ...	29·5	25·0	17·3	12·8	9·0	11·5
XIX ...	30·4	21·0	15·7	9·0	11·0	6·3
XX ...	25·2	21·6	13·2	12·0	7·8	7·5
XXI ...	28·2	11·6	12·7	9·9	9 8	10·5
XXII ...	31·8	20·4	15·6	13·5	13·0	9·3
XXIII ...	36·2	16·0	11·7	12·0	8·2	6·0
XXIV ...	30·0	25·2	21·8	12·5	7·2	10·1
XXV ...	23·0	20·6	9·6	4·4	9·2	13·0
XXVI ...	31·4	8·2	7·5	12·6	13·4	14·6
XXVII ...	23·8	16·4	16·4	15·7	16·6	9·7
XXVIII ...	20·2	24·6	20·2	21·3	12·8	9·9
XXIX ...	41·6	30·8	26·7	16·1	9·6	5·8
XXX ...	46·0	25·6	20·8	11·6	6·8	12·8

TABLE XV

Mean Values of Sets of 100, 200, 300, 400, 500, 600, and 700 Tests—Fibre-rigidity (4,000 Tests)

Group No	100's	200's	300's	400's	500's	600's	700's
I ...	2·15	2·06	2·31	2·18	2·11	2·15	2·21
II ...	1·98	2·38	2·19	2·10	2·16	2·22	2·23
III ...	2·79	2·25	2·10	2·18	2·25	2·26	2·20
IV ...	1·81	1·82	2·00	2·14	2·17	2·11	2·09
V ...	1·82	2·10	2·25	2·26	2·17	2·14	2·06
VI ...	2·38	2·46	2·41	2·26	2·22	2·12	2·00
VII ...	2·54	2·42	2·22	2·16	2·05	1·92	1·80
VIII ...	2·31	2·06	2·03	1·92	1·80	1·67	1·75
IX ...	1·80	1·89	1·80	1·67	1·56	1·66	1·70
X ...	1·99	1·79	1·63	1·50	1·63	1·67	1·93
XI ...	1·60	1·45	1·33	1·54	1·62	1·93	2·17
XII ...	1·30	1·20	1·52	1·63	1·99	2·27	2·10
XIII ...	1·10	1·64	1·74	2·16	2·46	2·24	2·10
XIV ...	2·17	2·06	2·52	2·80	2·47	2·27	2·30
XV ...	1·95	2·69	3·01	2·54	2·29	2·32	2·45
XVI ...	3·43	3·54	2·71	2·38	2·39	2·53	2·52
XVII ...	3·66	2·40	2·02	2·13	2·35	2·36	2·41
XVIII ...	1·14	1·20	1·62	2·02	2·10	2·20	2·30
XIX ...	1·27	1·87	2·32	2·34	2·42	2·50	2·60
XX ...	2·46	2·84	2·70	2·70	2·72	2·80	2·93
XXI ...	3·22	2·82	2·78	2·81	2·91	3·04	3·04
XXII ...	2·42	2·57	2·67	2·81	2·99	2·99	2·93
XXIII ...	2·71	2·80	2·94	3·13	3·11	3·06	3·15
XXIV ...	2·89	3·00	3·27	3·20	3·12	3·23	3·32
XXV ..	3·23	3·46	3·31	3·18	3·29	3·39	3·24
XXVI ...	3·69	3·35	3·17	3·31	3·42	3·24	3·18
XXVII ...	3·01	2·91	3·19	3·35	3·15	3·10	3·06
XXVIII ...	2·81	3·28	3·47	3·19	3·12	3·03	2·89
XXIX ...	3·74	3·80	3·31	3·20	3·07	2·90	2·81
XXX ...	3·86	3·10	3·02	2·91	2 74	2·66	2·64
XXXI ...	2·34	2 60	2·59	2·45	2·42	2·43	2·45
XXXII ...	2·85	2·71	2·49	2·44	2·45	2·47	2·53
XXXIII ...	2·58	2·31	2·30	2·35	2·39	2·47	2·56
XXXIV ..	2·05	2·16	2·28	2·34	2·45	2·55	2·51
XXXV ...	2·28	2·40	2·44	2·55	2·65	2·59	2·53
XXXVI ...	2·51	2·52	2·64	2·75	2·65	2·57	2·48
XXXVII . .	2·53	2·71	2·83	2·69	2 58	2·48	2·52
XXXVIII ...	2·89	2·98	2·74	2·59	2·47	2·52	2·42
XXXIX ...	3·06	2·66	2·49	2·36	2·45	2·34	2·27
XL ...	2·27	2·21	2·13	2·30	2·20	2·13	2·17

TABLE XVI

Values of Total Percentage Deviation from Fitness (*d*) for Sets of 100, 200, 300, 400, 500, and 600 Tests—Fibre-rigidity (4,000 Tests)

Group No.	100's	200's	300's	400's	500's	600's
I	35·8	25·8	12·4	11·0	10·8	10·4
II	23·2	18·2	16·7	15·3	10·0	11·6
III	42·4	28·2	20·8	13·1	13·4	12·8
IV	31·4	28·0	20·2	13·8	11·0	19·9
V	34·4	21·8	14·9	9·3	21·2	24·0
VI	31·9	25·0	19·2	29·2	29·6	22·3
VII	33·4	23·6	38·3	37·7	28·4	18·1
VIII	30·0	49·5	45·8	31·2	19·8	20·9
IX	83·0	59·2	37·6	23·2	25·0	21·8
X	42·6	18·4	23·3	31·2	29·0	29·1
XI	39·2	40·4	47·1	39·6	37·8	30·1
XII	51·8	55·8	42·7	42·4	32·8	27·8
XIII	64·0	40·8	43·3	35 7	30·0	25·2
XIV	19·8	37·6	35·6	28·8	22·3	22·7
XV	49·8	40·0	32·6	22·6	22·6	17·7
XVI	44·4	40·8	19·4	19·5	12·4	11·9
XVII	45·9	23·2	30·3	19·7	11·8	9·9
XVIII	60·8	54·8	32·4	18·4	13·2	10·2
XIX	57·6	28·8	13·9	10·9	10·2	10·2
XX	21·8	25·6	24·7	18·7	18·2	22·9
XXI	40·6	32·6	23·1	21·4	27·4	27·5
XXII	31·6	21·2	18·7	27·3	29·0	27·6
XXIII	31·0	24·8	34·3	33·8	30·9	28·1
XXIV	34·0	41·2	39·7	34·6	30·6	30·0
XXV	54·2	48·6	40·5	34·4	32·0	35·9
XXVI	58·4	40·8	32·8	32·5	34·8	27·7
XXVII	28·6	22·6	27·3	31·5	24·2	24·1
XXVIII	20·8	30·4	33·3	24·5	23·8	20·3
XXIX	45·4	42·6	26·4	25·6	20·8	16·3
XXX	51·6	23·6	22·7	17·8	12·8	11·2
XXXI	15·4	14·0	9·8	8·9	10·2	9·8
XXXII	22·6	15·2	12·3	12·7	11·6	10·8
XXXIII	20·2	17·6	16·4	14·1	13·2	14·1
XXXIV	25·6	21·6	13·4	14·1	13·6	15·1
XXXV	21·4	14·2	12·8	14·0	16·0	14·9
XXXVI	23·4	16·2	16·3	18·5	17·0	13·8
XXXVII	23·8	20·2	24·4	21·3	17·2	15·5
XXXVIII	25·4	29·0	24·0	18·5	16·4	12·0
XXXIX	42·4	30·0	21·3	17·7	11·6	9·0
XL	20·8	22·8	17·9	10·3	10·4	9·9
Mean	37·8	30·4	26·0	22·6	20·3	18·8

3—SOME NOTES ON THE PERMEABILITY OF FABRICS TO AIR

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INTRODUCTION

The permeability of fabrics to air is an important property on which little work has been done. Without measurement, it can be realised that the fabrics in ordinary use cover a very great range of permeabilities. For instance, a rubberised macintosh fabric is practically impervious to air while many of the light fabrics, especially cotton, silk, and artificial silk offer very little resistance to the passage of air.

The subject is significant in several connections. First and most obvious is windproofness which may involve relatively large pressures. The question of heat losses by convection is closely allied and in fact afforded the reason for starting the present work. This is treated in another paper by the present author[1] as also by Sale and Hedrick[3] in a study of the heat-retaining properties of fabrics. The pressures in this case, being due to convection, are much smaller. Thirdly, there is the permeability of fabrics to moisture which involves the measurement of the permeability to air. This has been recently studied by Gregory.[2] The subject also arises in connection with waterproofing of "porous" fabrics, the aim there being to produce a fabric impervious to water while allowing a free enough passage to air for hygienic purposes.

Previous Work

As far as can be ascertained, very few papers have been issued dealing with air permeability of fabrics.

Rubner in his "Lehrbuch der Hygiene" mentions some experiments on this subject. His results are given for 1 cm. thickness of material so are difficult to interpret. In the work of Sale and Hedrick[3] of the Bureau of Standards, connected with the heat insulation of blankets, the fabric was stretched across the top of a cylinder, the tension being 1% of the breaking strength. A tube led from the base of the cylinder to the meter, from which connection was made to an aspirator so that air could be drawn through the cloth. Another tube led from the middle of the cylinder to the top of a reservoir, which was connected to a micro-manometer. The flow of air during a period of time was measured by a damp gas-meter and the pressure in the cylinder was measured by the micro-manometer. The air was used at 70° F. and 65% relative humidity and eddies were prevented by placing a fine mesh wire partition in the cylinder just above the outlet. A variation of 4% from the mean was obtained from samples of the same fabric. They found a critical pressure below which all readings must be taken to get a constant permeability.

In more recent work at the National Physical Laboratory, Barr[4] passed air from a cylinder through the fabric. The pressure was measured by a special manometer in which the level in one limb is brought to a fiducial mark by a plunger in the other. The position of the plunger is a measure of the pressure. The quantity of air passing was measured by a flowmeter consisting of a capillary tube and manometer. He found a limit beyond which pressure and flow are not proportional and also that it was necessary to work with a definite humidity.

Gregory[2] used an apparatus very similar to that of Sale and Hedrick but the air was measured by timing the flow from an aspirator. An ordinary manometer, with one limb much larger than the other was used. He found very great variation between different samples of the same fabric.

Very recently there had been described a re-designed "Densometer."[5] A falling cylinder forces air through a known area of fabric and its time of fall is noted. The results are therefore essentially empirical but might be converted into absolute measurements with fair accuracy.

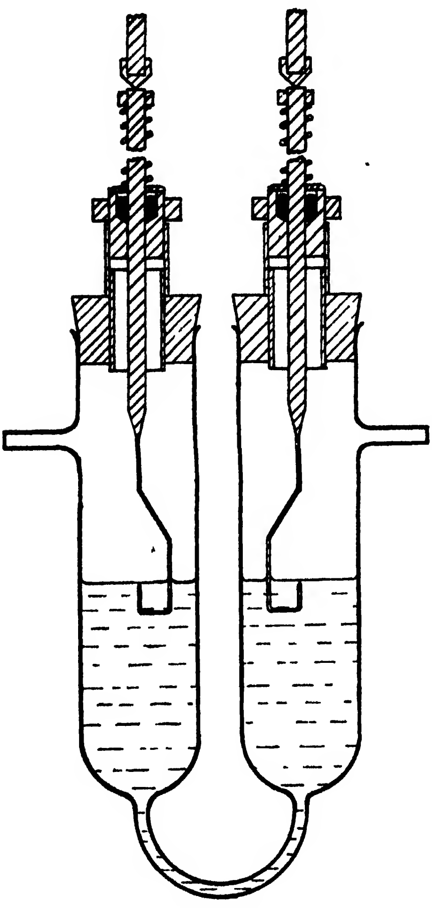


FIG 1

EXPERIMENTAL

Comparison with Fixed Resistances

The first method attempted was that of comparing the pressure drop through the fabric with that in a fixed resistance when the same stream of air passes through both. This would eliminate the need for measuring the quantity of air flowing as this can be deduced if necessary by calculation or by calibration of the resistance.

For the measurement of the pressures a three-limbed manometer is used. This was constructed of wide tubes connected by smaller ones in order to secure damping of any oscillations which might be set up. As, however, it was necessary in this work to investigate the behaviour under small pressure differences too small for an ordinary water manometer, a micromanometer was constructed. In general principle this is similar to the one described in the Dictionary of Applied Physics, Vol. I, page 640 (see Fig. 1). The limbs are 4 cm. wide connected by a 5 mm. tube. From the top of the limbs side tubes lead to the apparatus. This U-tube is firmly fixed to a board. and to this are also fixed steel blocks through vertical holes in which pass stainless steel rods. The upper ends of the holes are opened out and contain mercury which acts as an airtight seal. The steel rods are held by springs against two micrometer heads with pointed shoes on the anvils. To the lower ends of the rods, hooks are attached. The steel blocks are connected by rubber tubing to a wide tube passing through rubber stoppers in the U-tube. In this way it is possible to get a rigid hook gauge without imposing undue stresses on the glasswork of the apparatus. Hook gauges were found to be preferable to dipping point gauges as they are less liable to error from vibration of water surface and the approach of the point to the surface can be seen by reflection in the water surface when viewed from below. These features were felt to outweigh the advantages

of the very sharp rise of the water surface when the dipping point touches the surface. With this instrument it is possible to read to 0·02 mm. with practice without the use of a microscope. Strong, diffuse illumination of the point from the back was found to be a great help in accurate setting.

The source of air pressure used was a 4 in. centrifugal fan driven by an A.C. induction motor. This gave a very steady air supply owing to the constant speed of the motor. This fan could be arranged for blowing, suction, or circulation. In the last case the rest of the circuit is made airtight as communication to the outer air was provided by leakage through the ball bearings on the fan shaft.

The arrangement of apparatus for the comparison of a fabric with a standard resistance differed with the resistance used.

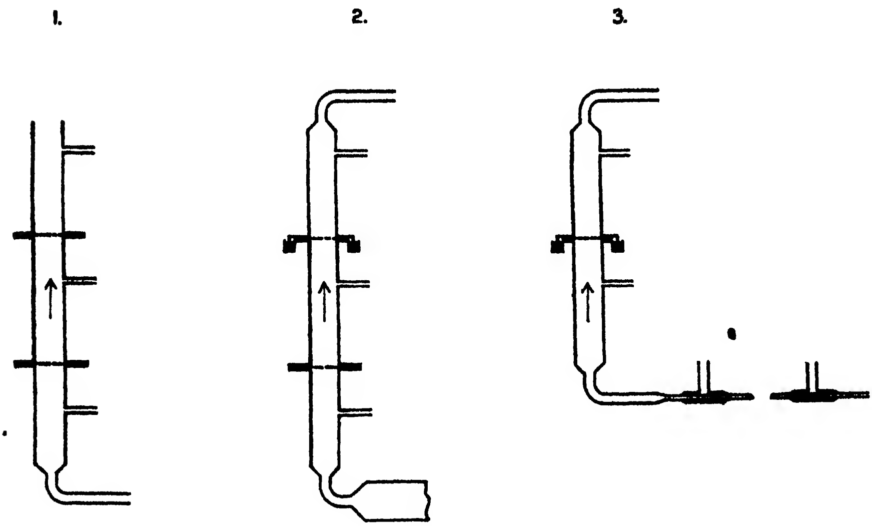


FIG. 2

The first arrangement is shown in Fig. 2 (1). A tube was provided with two flanged joints which could be held together with spring clips. The fabric was put into one and the orifice plate into the other, an air-stream passed, and the two pressure differences measured. The top of the tube was open. Care was taken to see that the flanges registered with each other. A difficulty was encountered when the apparatus was run for more than a short time as the fabric became choked with dirt. It was then decided to make a closed circuit including a filter containing wool soaked in glycerine. The tube was then modified to that shown in Fig. 2 (2). Leakages from the edge of the fabric were prevented by a mercury seal. With this arrangement the results were fairly consistent and the following types of resistances were used.

(1) *Orifices*—Holes were drilled in thin metal plates and all burrs carefully removed. These were clamped in the lower flanged joint between rubber washers.

(2) *Wire Gauze*—The gauze was heavily varnished before use, leaving only a defined area in the centre.

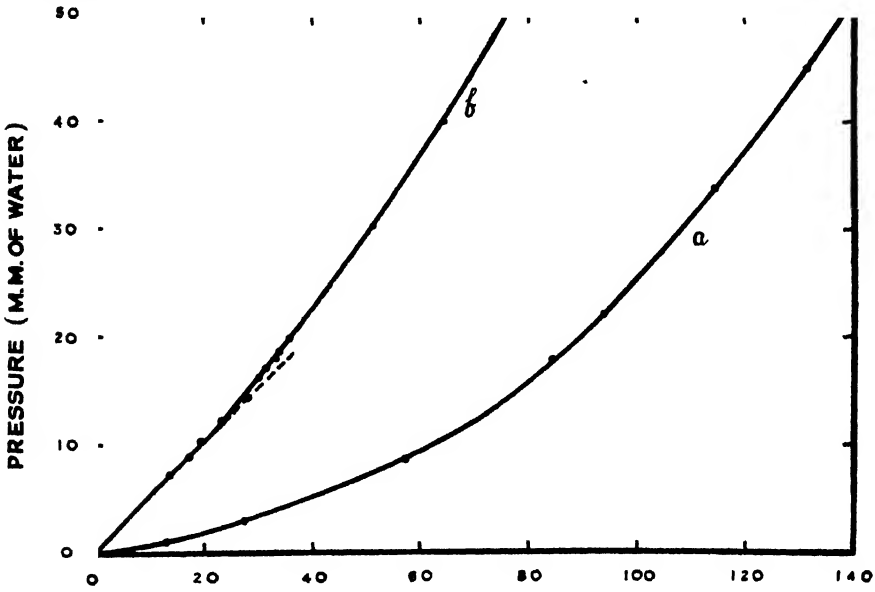
(3) *Capillary Tube*—The tube was fitted with a central flange so that it could be gripped between the flanged joint.

(4) *Glass Wool*—A wider tube was put in the flange and packed fairly lightly with glass wool.

(5)—*Tapped Tube*—A long glass capillary tube (1 mm. diameter approx.) was drilled near its ends and T tubes slipped over and waxed in position. The two limbs perpendicular to the tube were connected to a manometer (See Fig. 2 (3)).

Calibration of Resistances

From preliminary comparisons of these different resistances among themselves it was found that the orifices, wire gauze and tube behaved similarly in not giving a straight line relation between pressure and volume per second, while the glass wool resistance and tapped tube gave an approximately straight line. It was therefore decided to take the orifice and tapped tube as the representative of each class and calibrate them more accurately.



(*a*) Orifice (*b*) Tapped Tube

Fig. 3

In the preliminary work a large calibrated vessel was filled with water from a constant head apparatus thus forcing air out through the orifice or tube to be calibrated. By allowing water to enter at the top, all difficulties of varying head were eliminated. The inlet tube was surrounded by a wide glass tube to prevent splashing and the general spread of air bubbles. The time at which the water surface passed certain graduations was stop-watched. No temperature or humidity control of the air was used as, after a few measurements had been taken, a better method of calibration was adopted.

Air from a controlled room at 70% R.H. and 73° F. was drawn through the resistance and metered by a standard wet type gas-meter of known accuracy. The results were much more consistent than with the other method.

Fig. 3 shows the calibration of an orifice and one of the tapped tubes used. It will be seen that the orifice gives the parabolic relation which would be

expected while the tapped tube gives a straight line at first and then a curve. The reason for this curve is that the flow becomes turbulent. The critical point at which this happens is low compared with that given by Osborne Reynold's formula—

$$\frac{V_c d \varrho}{\eta} = 2000$$

where V_c = critical velocity.
d = diameter of tube in centimetres.
ϱ = density in grms. per cc.
η = coefficient of viscosity.
(*Dict. App. Phys.*, Vol. I, page 35.)

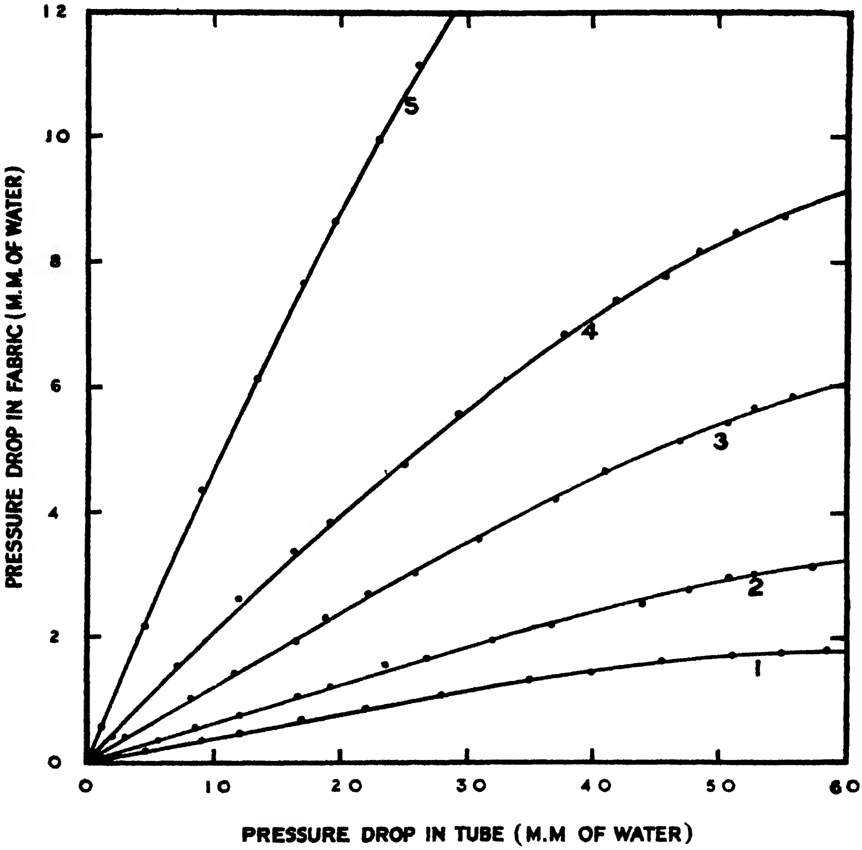


FIG 4

In this case d=0·25 cms., ϱ=0·00012 grms. per cc., η=0·00018 C.G.S. units giving a critical velocity of 168 cms. per second, which is equivalent to 60 cc. per second. The reason for this low value may be that the tappings were near the ends of the tube and when the critical velocity was approached disturbance may have been set up by the ends.

From these results it was deduced that for most fabrics, there is little deviation from a straight line relation between pressure difference and flow.

In this work the main interest is in the permeability at very small pressure differences. This may be taken as measured by the gradient of the curve

at the origin. With the parabolic form of curve such as is given by the orifice this gradient is very difficult to obtain but is relatively easy in the case of the straight line given by the tapped tube. The tapped tube is, therefore, a very suitable standard. The only other one with the same law was the packed glass wool, but this is liable to change if jarred in any way.

Using the tapped tube, many measurements on fabrics were carried out. Typical results are given in Fig. 4. The fabrics in order starting from the lower one are (1) flannels, (2) and (3) artificial silk fabrics, (4) flannel suiting. (5) waterproofed coating.

Comparison of Fabric with Fabric

This method allows one fabric to be compared with another very rapidly. The two samples are put into the two flanged joints of the apparatus shown in Fig. 2 (2). It was found that, in general, the relation between the pressure drop in the two for various rates of flow was not a straight line although not a very great deviation from it.

It was felt, however, that the method was not satisfactory owing to the facts that—

(1) The standard is not repeatable once it is disturbed.

(2) The permeability of a cloth alters with humidity and dirt.

It is mentioned here as it might be useful as a rough commercial test.

Direct Measurement of Resistance

In all the work mentioned above, it was felt that there would be considerable difficulty in getting controlled temperature and humidity. It was found that slight variations of air permeability with time were caused by the conditioning of the fabric.

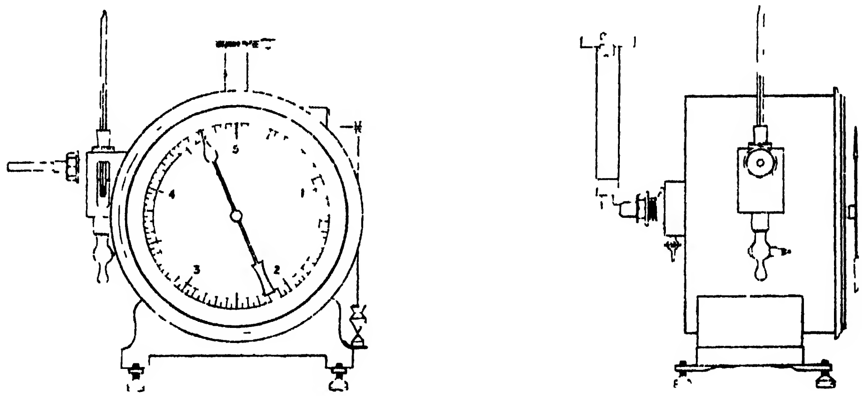


FIG. 5

This was entirely eliminated by using a method similar to that of Sale and Hedrick, the only essential difference being that the fan was used instead of an aspirator. A wet type gas-meter was employed and this with the fabrics to be measured was kept in a constant temperature and humidity room. Thus the whole apparatus was at constant temperature and the fabrics were in equilibrium with the air passing through them. All variation of permeability with time was thus entirely eliminated and this method was used in the measurement of many fabrics for other purposes. It was also verified that the flow per unit area of the fabric is independent of the area. This was done by enclosing it between plates in which registering holes of various sizes were drilled.

Large variations were found from point to point in most fabrics. This might be eliminated to a certain extent by using samples of large area, but this would need a fan and meter too big to be convenient in the laboratory.

For each determination of permeability a number of readings of pressure and rate of flow were made and plotted on a curve. This was in general only a very slight deviation from a straight line and passed through the origin. The gradient of the curve at the origin was taken as a measure of the permeability of the fabric and the absolute value calculated as the volume of air (at 73° F., 760 mm., and 70% R.H.) passing through 1 sq. cm. of the fabric under a pressure of 1 cm. of water. This determination was repeated at a number of places on each sample when accurate results were desired but in some of the work for which the apparatus was used the range of permeabilities was so great that it was sufficient to get the order of the result and only one determination was necessary.

Typical results are shown in Fig. 6. This apparatus was used in connection with work on thermal insulation, which should be referred to for detailed results of many different types of fabric. A few examples are given below.

Description of Fabric	Details of Weave or Knitting	Permeability (in cc. per sq. cm. per gm. per sq. cm.)
Knitted artificial silk	28 wales. 32 courses	1225
Artificial Silk (Celanese)	Plain weave	981
Sheer linen	Plain weave	700
Aertex cotton	342 holes per sq. in.	377
Knitted wool	26 wales. 34 courses	363
Aertex cotton and artificial silk...	736 holes per inch.	306
Aertex cotton and wool	121 holes per inch	280
Knitted cotton	25 wales. 36 courses	252
Yorkshire flannel	Plain weave	153
Pure silk crepe-de-chine	Plain weave	140
Knitted wool	20 wales. 26 courses	121
Artificial Silk (Celanese)... ...	Plain weave	89
Wool blanket	Plain weave	89
Army blanket	Plain weave	58
Wool and cotton blanket ...	Plain weave	49
Pure silk taffeta	Plain weave	45
Wool blanket	4-shaft satin weave	45
Naval suiting	2/2 Twill weave	43
Flannel (Yorkshire)	Plain weave	43
Angola shirting, wool and cotton	Plain weave	41
Wool and cotton blanket ...	Plain weave	41
"Aero" linen	Plain weave	18
Unbleached calico	Plain weave	14
Proofed coating	2/2 Twill	10
Woollen undercoating	2/2 Twill	10
Felt	... ...	10
Artificial Silk (Celanese)	2/1 Warp Twill	10
Khaki overcoating	2/1 Weft Twill	7·3
Barathea	2/2 Twill (Hopsack)	5·7
Linen duck	Plain weave	2·8

Uses

As mentioned before, permeability to air comes up in several branches of the study of fabrics. The apparatus described has been used in connection with thermal insulation, windproofness, and waterproofness.

A further use, which is thought to be new, has been found. It is now being investigated fully but preliminary results may be mentioned here. When

a fabric is milled its permeability to air decreases to a marked extent. This effect was first discovered in felts but it also applied to all kinds of cloths. Several examples are given below of low woollen cloths commercially milled.

Description	Volume passing per sec. for pressure of 1 cm.		Percentage Decrease
	Unmilled	Milled	
Low woollen cloth 1	56	39	30%
Low woollen cloth 2	96	63	34%
Low woollen cloth 3	93	38	59%
Low woollen cloth 4	74	58	22%

A cream woollen cloth showed a decrease of 38% on normal milling and 65% when the milling was carried on to an abnormal extent.

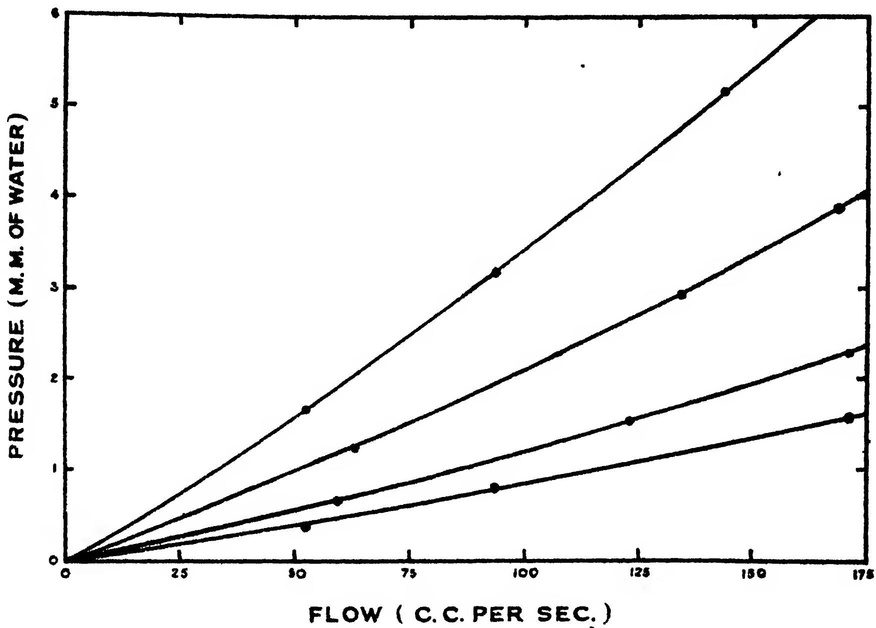


Fig. 6

These figures are of a preliminary nature only but show clearly that there is a definite decrease in permeability on milling. Attempts are now being made to find the relation between time of milling, permeability, thickness, and shrinkage. The results will be given in a later paper. It is possible that permeability to air may be used as a measure of the amount of milling of a fabric.

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4—EXPERIMENTS IN FABRIC WEAR TESTING—I

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INTRODUCTION AND SUMMARY

Among the points upon which information is required in connection with the design of a satisfactory wear tester are the following—(*a*) The effect of varying the manner in which the test-piece is mounted in the machine: (*b*) The nature of the progressive fall in strength as the wearing proceeds; and (*c*) The relation between the two criteria of the resistance to wear which, in addition to that of appearance, have been so far suggested, namely, loss of strength, and loss of weight. These are dealt with in the first part of the paper in so far as they affect the machine used, which was the same as that already described by Morton and Turner.[3] In this machine, the sample is cut to a two-inch width, is clamped at each end over a specially ridged base-plate, and is subjected to a to-and-fro abrasive action of a suitably loaded but non-revolving "Carborundum" cylinder which rests upon it.

Under the heading of (*a*) it was found that for practical purposes it is immaterial what tension is used for mounting the test-piece over the base-plate; under (*b*) it was found that the manner in which the strength of a fabric is reduced during its wearing life cannot be assumed to be the same as for any other fabric, since it depends on the precise nature of the warp and weft interlacement; while under (*c*) it was not found possible to reconcile the two quantities concerned.

Consequent upon the findings under (*b*), an additional test was made to determine whether the tension on the warp during weaving has any effect on the wearing properties of the fabric. The results were on the whole negative, but it was found that the warp tension affects the breaking load to a considerable extent The latter finding will form the basis of a further communication.

The second part of the present paper is concerned with the consistency and reliability of the abrasive medium itself, the objects of the tests being to obtain some idea of the effective life of the "Carborundum" cylinder, and to probe the question of finding an abrasive which could be standardised. The results of these experiments indicated that, while there ought to be very little difficulty in designing an instrument which over a long period will give consistent results in comparative tests, the problem of standardising an abrasive such that any one machine will give the same results as any other under similar conditions will be very difficult if not impossible to solve.

During the course of the second part of the work, it was found necessary to re-design the cross-head that carries the "Carborundum" cylinder in order to allow a greater proportion of the surface of the latter to be utilised in each test. The modifications of the original design which are involved are described.

EXPERIMENTAL METHOD

In the experiments described here, the measure of a fabric's resistance to wear was taken as the proportion of original breaking strength remaining in the samples after a definite period of rubbing. This method of estimating the effect of wearing seems to be preferable to those adopted by

Hasler,[1] Kapff,[2] Repenning,[3] Smith[5] and Myers,[4] in which the wearing quality of the fabric is either judged by the change in its appearance, or measured by the length of time required to wear it out completely. It is true that in certain finished cloths, changes in appearance caused by wear are more important than changes in strength, and consequently the former method would appear to be the most suitable in such cases; but on the other hand, the test leaves too much to the personal judgment of the observer, and the results cannot be expressed in figures.

The second alternative method given above also has its disadvantages; for not only is a greater length of time needed for the test, but also, with the machine as used for the present work, very irregular results are obtained. This is principally owing to the irregular manner in which the first small hole that appears spreads across the whole of the test-piece under the plucking action of the abrasive.

The method of testing is as follows. A sample nine inches long by two and a quarter inches wide is cut from the piece of cloth to be tested in exactly the same way as samples are cut when testing for cloth strength. The sample is frayed down until it is two inches wide, and, where the rubbing is to take place, the edges are carefully trimmed. It is now placed in the jaws of the wear tester so that it is exactly parallel to the path of the "Carborundum" stick. The tension on the sample must be uniform all across its width. A suitable way of ensuring this is to fasten the sample securely in the back jaws and to attach a suitably loaded paper clip to the other end, allowing it to hang freely over the end of the bed-plate; then to tighten up the front pair of jaws.

The rubber is set in motion and allowed to act upon the fabric for a suitable period of time* which should be determined by trial before the experiment proper is commenced. On the expiration of the time of rubbing the machine is stopped and the sample is removed from the jaws and tested for strength in the ordinary way on a Goodbrand cloth tester. Then a similar sample of cloth, taken from the same piece, and made from the same warp ends if the test is being carried out warp way, or from the same picks if the test is being carried out weft way, is tested for strength without having been rubbed in the wear tester. The figures thus obtained show how much strength the fabric loses due to the abrasive action of the "Carborundum;" and by repeating the test about ten times a significant value for the mean strength lost can be obtained.

In every case the order of testing was arranged so that any change in atmospheric conditions, or in the abrasive properities of the "Carborundum", would be averaged out over the whole test. Thus, for example, if ten tests are to be made from four different fabrics, number one sample from each lot in succession is tested, followed by the number two samples; and so on until all ten of each are tested. In a like manner, where a number of lots from the same cloth are being tested to observe the effects of varied treatment, the samples are so taken that whatever variations exist in both warp and weft are as far as possible represented equally in all the lots. For simplicity of reference on future occasions, this general precautionary system will be referred to as the "Rotary" system of sampling.

*In the later stages of the work, a Veeder counter was fitted to the machine, so that a constant number of rubs was substituted for a constant period of rubbing.

THE SIGNIFICANCE OF THE VALUES OBTAINED

Twenty warp way samples were taken from the same piece of bleached calico having 78 ends per inch, 64 picks per inch, 30's warp and 30's weft, and were each subjected to three minutes' rubbing. The unrubbed breaking load of this particular cloth had previously been found to be 72·1 lb. per two inch width, and the load on the rubber was adjusted so that the samples lost about 50% of this in the time given. The results of the strength tests on the samples worn in this manner were as follows—

45, 46, 40, 44, 46, 43, 43, 44, 47, 41,
42, 47, 43, 41, 44, 34, 38, 41, 36, 48,
Mean=42·6 ± 0·5 lb.

From these figures it was decided that ten tests would be enough to ensure a sufficiently accurate mean, since the probable error of the mean would then be only about 2%; and throughout this paper, unless it is stated to the contrary, it may be taken that this number of tests were made in the determination of each mean.

THE EFFECT OF VARYING THE TENSION EMPLOYED IN MOUNTING THE SPECIMENS

In this experiment four plain cloths were used having the following particulars—

(1)	Balloon type fabric	132/128	60/70
(2)	Light weight fabric	68/68	32/26
(3)	Medium weight fabric	70/80	28/26
(4)	Heavy weight fabric	69/36	25/7½

The various tensions were obtained by suspending suitable weights to the paper clip used for mounting the samples. For fabrics 1, 3, and 4, the weights employed were 1·0 oz., 8·5 oz., and 15·3 oz., all the specimens being rubbed for three minutes before being tested for strength. In the case of fabric number 2, which was tested at a later date, the weights were 2·7 oz., 9·7 oz., and 17·7 oz., with a period of rubbing of 1¾ minutes. At regular intervals during the test, unrubbed samples of each type of cloth were tested for strength in the same way in order to determine the strength lost.

The results are given in Table I, from which it is seen that within the limits employed, the tension on the sample has no significant influence on the strength lost by the fabric during wearing. In no case is the ratio $\frac{\text{Difference between means}}{\text{P.E. of the difference}}$ greater than 2·4*.

As a result of this experiment it is evident that no special precautions need be taken to ensure constant tensions in all the samples; in inserting the samples in the machine it is only necessary to pull them tight so that they lie flat on the base-plate.

Theoretically an increase in the tension on the sample ought to cause the cross threads to rise more to the surface of the fabric and so cause them to wear away more quickly (see p. T67).

*It is recognised, of course, that the values of the probable errors are only approximate in cases like this where the numbers of observations are small.

It may therefore be assumed that the tensions likely to be used in adjusting the samples between the jaws of the tester are not great enough to affect the relative positions of the warp and weft threads.

Table I

Fabric	Breaking Load in Lb. per 2-in. Width: Before Wearing	After Wearing: Low Tension	Medium Tension	High Tension
No 1 Warp Wap	100·0	77·4 ± 2·0	73·5 ± 1·4	77·0 ± 1·8
No. 2 ,, ,, ...	59·8	37·1 ± 0·9	39·3 ± 0·8	36·6 ± 0·8
No. 2 Weft Way	76·8	41·1 ± 1·0	40·6 ± 0·6	42·2 ± 1·1
No. 3 Warp Way	68·8	52·0 ± 1·2	47·9 ± 1·4	49·1 ± 1·6
No. 4 ,, ,, ...	167·0	135·4 ± 1·2	136·1 ± 3·1	136·5 ± 1·6

THE MANNER OF WEAR OF COTTON FABRIC

The way in which cotton fabrics lose strength during the laboratory test was studied for a large number of fabrics by maintaining a constant load on the abrasive, and observing the strength lost after varying rubs. The relation between strength and period of abrasion has already been tentatively examined by Morton and Turner, and it has been suggested that the nature of the relationship is very largely influenced by the extent to which one or other of the sets of yarns predominate on the surface of the cloth. The tests carried out by us support and amplify this conclusion.

In the cloth in which the ends and picks are the same, and the counts of warp and weft are the same, this depends principally on the relative "take-ups."* Thus, when the "take-up" is greater in the warp direction than in the weft and when the test is made in the weft direction, a certain amount of energy has to be expended in wearing away the warp before the abrasive can effectively attack the weft. In such a case the plotting of strength against the rubs will show a relatively flat-topped curve for the initial stages of wearing (see Fig. 3).

The extent of this relatively flat top will depend presumably, on the degree of protection which the warp affords the weft and this, in turn, will be conditioned by the relative "take-up" and the relative quality of the yarns.

Under the same conditions when the test is made in the warp direction, the warp threads are exposed to the abrasion straight away, and the wear-strength curve will show a relatively sharp decline from the beginning, flattening out later according as the gradually exposed weft threads absorb an increasing proportion of the wearing energy (see Fig. 3).

Where there are differences in ends and picks, and in counts and qualities of warp and weft, the relative yarn "take-ups" are no longer indexes of the degree of protection afforded to one set of threads by the other, but the shape of the wear-strength curves will still be determined on the same general principle.

Consideration of the foregoing, and the results of tests made on many different fabrics, show that the progressive weakening of a fabric, due to wear in any given direction cannot be characterised by any simple law: and from this it follows that the strength lost after a given number of rubs is no basis for computing the strength which would be lost after any other number of rubs.

*This word has been adopted as descriptive of that function of a woven yarn which is variously termed "regain," "crimp," "take-up," etc.

DEFINING WEARING QUALITY

Wearing quality other than as determined by appearance, may be defined in two ways, either (1) as the strength remaining after a given amount of abrasion, or (2) as the amount of abrasion necessary to reduce the strength to a given figure. If the amount of abrasion is the constant factor, it is possible for a comparison between two fabrics to produce different results depending on the amount of abrasion decided upon. This arises directly out of the variation that exists from fabric to fabric in the shape of the wear-strength curve. An hypothetical example of this is provided in Fig. 1, where fabric A would be shown to be the better at 150 rubs and the poorer at 350 rubs. How often such an event as this will occur in practice, it is difficult to say, but the possibilty of it happening cannot be ignored. The selection of the most appropriate testing conditions is therefore likely to prove a difficult problem.

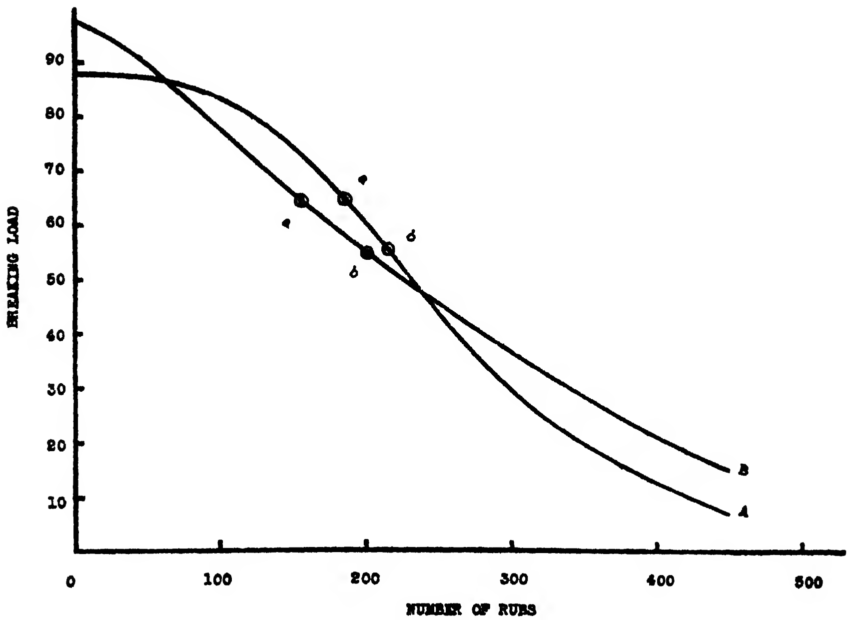

Fig. 1

In so far as strength may determine the life of a fabric, it would be more reasonable to define the wearing quality as the amount of abrasion it will stand before the strength is reduced to some unsafe limit. Such a definition, however, would involve a rather more complicated testing procedure. In the case of each fabric, trial and error tests with single test-pieces would have to be made to determine the number of rubs which, with a suitable load on the abrasive, would result in (*a*) a worn strength slightly greater than the previously fixed "safe" limit, and (*b*) a worn strength slightly less than the "safe" limit. With a little experience, this may be done in a matter of five or ten minutes. In this manner, two conditions of test would be decided upon which, when, say, 10 tests have been made under each, would give two points on the wear-strength curve in the neighbourhood of the "safe" strength, as illustrated at *aa* and *bb* in Fig. 1. Provided these points are

not too far apart, the number of rubs necessary to produce exactly the "safe" strength may then be found with very little error by interpolating on the assumption that the wear-strength curve is a straight line between the points.

But here also, there is the problem of defining the testing conditions. It will be seen that fabric A would be shown to be better than B if the limiting strength were fixed at 70 lb. Logically, the comparison should be made under conditions which correspond to normal usage; but the magnitudes of the stresses which ultimately cause the breakdown of fabrics in actual use are unknown in all but very rare cases; and futher they cannot be inferred with any degree of accuracy from the original fabric strengths.

It would seem, therefore, that with neither of the above definitions of wearing quality can conditions of test be prescribed which will represent actual usage with accuracy. Testing to destructions presents a no better case; for it is really only a particular form of the testing conditions referred to in the last paragraph, and the liability to produce fallacious results is, if anything, at a maximum.

In the circumstances it would seem best to adopt that form of test which is the simplest and most quickly made. It is suggested, therefore, that wearing quality be measured by the strength left after a given amount of abrasion. The "given amount of abrasion" is a quantity compounded of the abrasive properties of the cylinder, the load on the cylinder, and the number of rubs; and must be prescribed arbitrarily by the tester according to circumstances. Our own experience is that the test is made most conveniently and accurately when the amount of abrasion is fixed so that the loss of strength is round about 50 per cent. In fabrics where, in use, the wearing and stressing both operate principally in one direction--say the warp—then the tests are made only in the warp direction; but where a fabric is subjected to wear and stress in both directions equally, tests are made in both warp and weft directions; and whichever of these has the lowest residual strength determines the wearing quality.

THE RELATION BETWEEN LOSS OF STRENGTH AND LOSS OF WEIGHT

For the testing of jute matting and other similar fabrics it has been suggested that the wearing properties can be estimated by the weight lost during a given period of abrasion. For general purposes, however, and especially with the test method used here, this does not appear to be as accurate as determining the loss of strength, since many fabrics, particularly the lighter types, lose very little in weight, and the risks of experimental errors are much greater. Furthermore, it is extremely difficult to remove all the fluff from the worn sample. Investigations were carried out however to ascertain whether any relationship exists between the strength lost and the weight lost by any particular fabric duration abrasion.

Four groups of ten samples each were treated in the wear tester for 100, 150, 200, and 250 rubs respectively. The samples were weighed on a chemical balance before wearing; brushed gently to remove the fluff and loose fibre after being subjected to the required amount of abrasion; tested for strength in the usual way; and the broken samples again weighed to determine the weight lost. The results obtained are shown in Table II and plotted in Fig. 2.

It will be observed that while the curve for strength lost rises rapidly at first and more slowly later, the curve for weight lost does exactly the opposite, rising gradually at first and more rapidly afterwards.

This is due to a combination of two circumstances. In the first place, it requires only a small number of fibres to be removed from the exposed surface of the yarns to upset the equilibrium of their structure and so cause considerable loss of strength; and futher abrasion, while continuing to damage fibres hitherto unaffected, continues also to remove portions of those fibres whose usefulness has already been impaired by previous severance. And in the second place the weight lost is that of both warp and weft, whereas the strength lost is measurable in only one direction. On this account, whatever relationship exists between these two quantities, will vary from fabric to fabric according to the relative amounts of warp and weft on the surface.

Table II

Number of Rubs	Strength Lost lb	Weight Lost mgms.
100	77·0	1·69
150	99·7	2·34
200	110·3	3·70
250	125·6	5·13

Strength before wearing equals 175·3 lb.

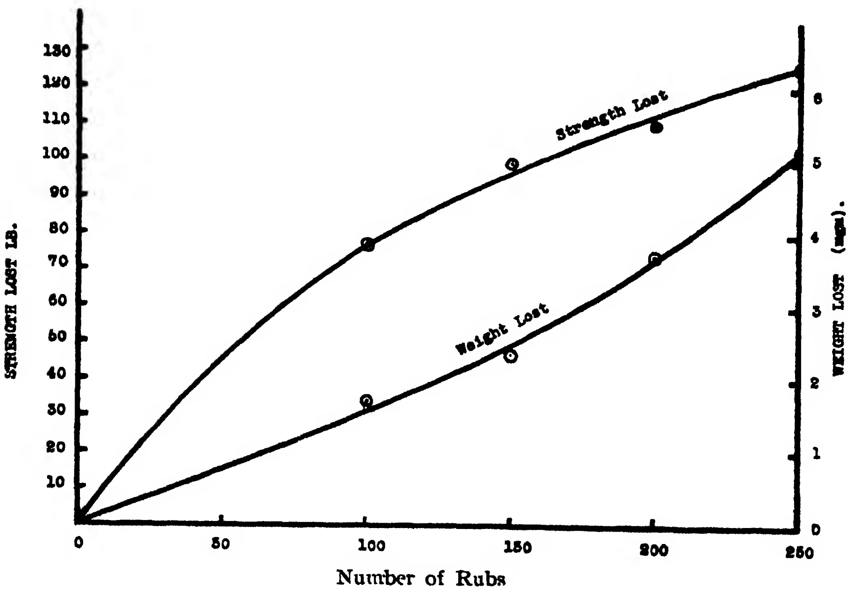

FIG. 2

THE INFLUENCE OF WARP TENSION DURING WEAVING ON THE WEARING BEHAVIOUR OF PLAIN CLOTH

Following on the findings to which reference has just been made, experiments were next carried out to determine the extent, if any, to which the warp tension might be capable of so changing the take-ups in the two sets of threads as to change the wearing properties of the fabric.

Tests were made with three different plain fabrics, varying warp tension in each case being obtained by adjusting the weights on the let-off motion.

It was hoped that, in at least one of the cloths tested, the low tension might leave the warp with the greater regain, and that the higher tension would make the weft do the greater amount of bending; but this was not realised. In the first cloth tested, which was almost a poplin in structure (76 × 70, 2/50/32), the ends were too close together to allow the weft to do any more than a limited amount of bending. Consequently, although the high warp tension decreased the warp regain while increasing that of the weft, the former still remained the greater (see Table III). In the case of the second cloth tested (78 × 72, 32/40), the same state of affairs existed, though to a lesser extent, and the differences between warp and weft regains were, therefore, not so great. On the other hand, the third cloth tested (72 × 72, 36/40), was of such a structure that even with the low tension the weft regain still remained considerably greater than that of the warp.

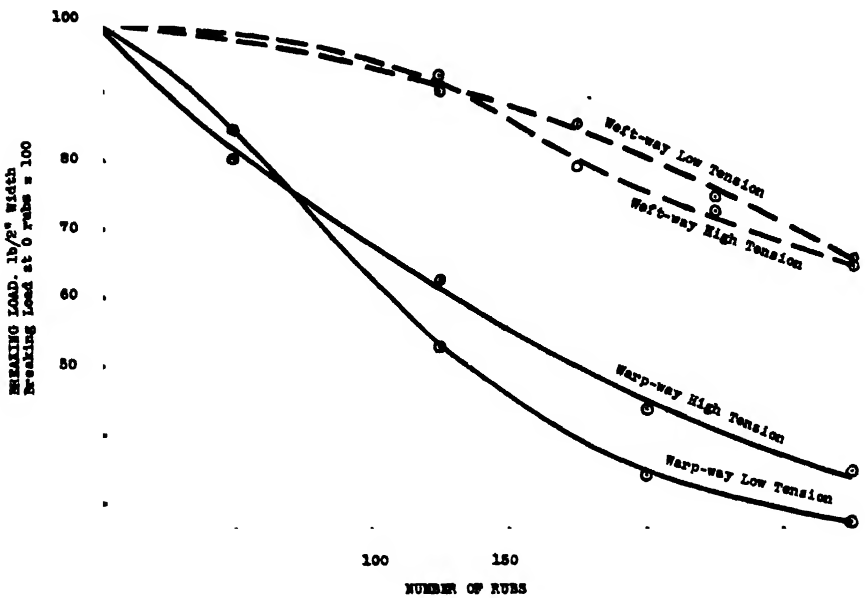

FIG. 3

Fabric No 1 76 × 70 2/50 32

In each case the wear-strength curves of warp and weft directions were obtained by subjecting the fabric to varying numbers of rubs, the load on the rubber being adjusted to suit the character of the cloth. The results are given in Table III, and the curves for two of the fabrics are given in Figs. 3 and 4.

In general it was found that in all three fabrics, varying the tension during weaving produced only a small change in the shape of the wear-strength curves. This was so even in the case of the first fabric, where the increase of tension produced a considerable change in the relative regains; the weft curves both showed a prominent flatness at the beginning, and the warp a corresponding sharp decline. This seems to indicate that the wearing quality of a fabric is very sensitive to the degree of yarn exposure on the surface, a possibility easily understood, since, as already stated, it requires

only a little of the yarn surface to be removed before the bending forces holding that yarn together are set free.

On the whole, the results obtained were inconclusive, although it is possible that certain structures in which the regains might respond more sensitively to the warp tension during weaving might show some effect.

It will be observed that in Fabric No. 3 it is the warp curve that shows the flat top at the beginning, and not the weft curve, as in Fabric No. 1. In the former case the ratios of warp to weft regains are less than unity, while in the latter the ratios are greater than unity (see p. T71).

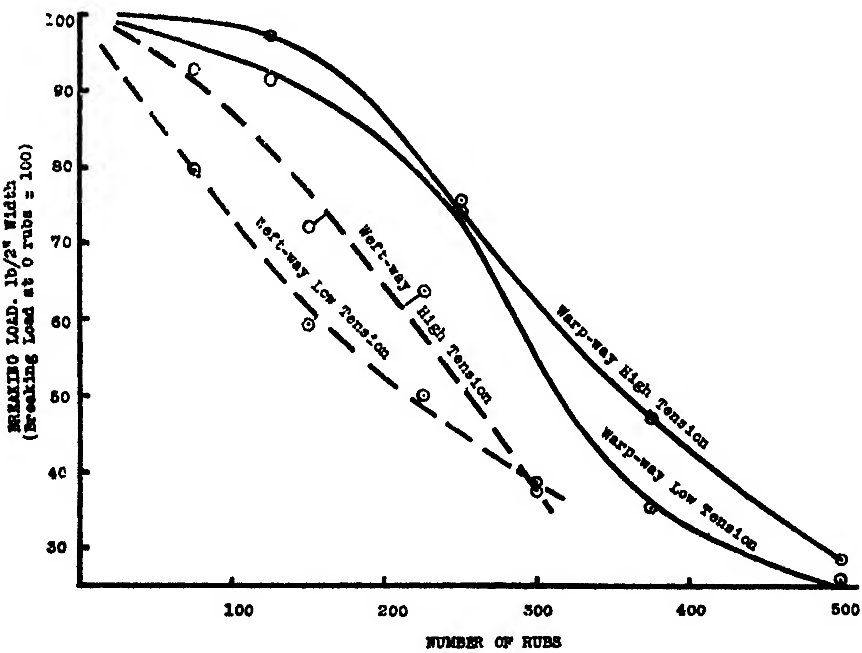

FIG 4

Fabric No 3. 72×72. 36/40

In plotting the curves in Figs. 3 and 4, the values of the unworn strength have been taken as 100 in each case in order to simplify comparison as to curve shape; but reference to the actual strengths given in Table III brings up an interesting point in connection with the effect of warp tension on fabric strength. Fabric No. 1 shows a very considerable increase of strength in both warp and weft as the tension increases. The fact that the same effect is less evident in Fabric No. 2 and not at all in No. 3 indicates that it is restricted to certain structures, but it is evidently of some importance, and further research is being undertaken to investigate the matter more fully.

Table III

Fabric	Warp Tension	Regain %	Breaking Load unrubbed lb	Breaking Load after Wearing, Lb			
				50 rubs	125 rubs	200 rubs	275 rubs
No. 1, Warp way	High	10·9	224·9	180·4	140·5	98·0	77·6
	Low	19·4	188·6	159·6	99·8	63·9	51·3
				125 rubs	175 rubs	225 rubs	275 rubs
Weft way	High	8·5	101·0	93·8	79·8	73·4	65·5
	Low	5·3	87·8	79·1	74·9	65·6	57·4
				100 rubs	250 rubs	400 rubs	550 rubs
No. 2, Warp way	High	5·4	98·5	93·9	64·9	40·5	19·1
	Low	7·3	96·1	93·1	67·9	41·9	19·0
Weft way	High	5·1	90·5	84·8	61·9	44·6	-
	Low	5·3	79·8	70·3	57·5	41·3	24·2
				125 rubs	250 rubs	375 rubs	500 rubs
No. 3, Warp way	High	2·9	63·3	61·6	49·5	29·9	17·9
	Low	3·6	63·3	58·0	47·9	22·3	16·4
				75 rubs	150 rubs	225 rubs	300 rubs
Weft way	High	11·9	79·9	74·1	57·9	50·9	30·0
	Low	11·6	77·8	62·0	46 1	38·8	30·0

CONSIDERATIONS OF THE ABRASIVE

The Consistency of a Single "Carborundum" Cylinder

At regular intervals throughout certain of the foregoing experiments tests were made to see if the prolonged use had any effect on the abrasive properties of the "Carborundum" cylinder. The fabric used for this purpose was an ordinary calico, 70/70, 30/30. One sample of this was rubbed for three minutes and tested for strength in the usual way after ten tests in the above-mentioned experiments. The results are shown in Table IV from which it is evident that no deterioration took place in the wearing power of the "Carborundum" during the space of time occupied by the test, about ten hours' continuous abrasion.

Table IV

Mean Breaking Load before Wearing 70·5 lb.

Sample No	R. H % during Test	Test made after	Breaking Load after Wearing, lb
1	82	10 tests	50
2	88	20 ,,	42
3	84	30 ,,	50
4	87	40 ,,	46
5	82	50 ,,	48
6	80	60 ,,	45
7	82	70 ,,	48
8	82	80 ,,	42
9	86	90 ,,	50
10	80	100 ,,	48
11	78	110 ,,	47
12	72	120 ,,	45
13	72	130 ,,	40

The Variation in a Single "Carborundum" Cylinder

In the wear tester as described by Morton and Turner the carborundum cylinder was fixed so that one surface only was maintained in use. After prolonged abrasion that face would undoubtedly be worn flat and a fresh face would have to be brought into operation. It was desirable, therefore, to know whether the cylinder possessed the same abrasive properties all round its surface.

The surface of the cylinder was divided into eight parts by means of marks made with white paint on the end of it. A similar mark was made on the bracket in which the cylinder was carried. Warp samples of the usual dimensions were cut from a cloth of the following particulars—78/42, 2/50/24.

The cylinder was fixed in the machine so that one of the marks on its end was opposite the mark on the cross-head. One of the samples was placed in the tester and rubbed for three minutes, its strength being then found. The cylinder was now loosened and turned round until the next paint mark was opposite the mark on the cross-head, and another sample was tested. This order was repeated until each of the eight portions of the cylinder had been used, and then until ten results had been obtained from each portion. By adopting this order of testing, a satisfactory mean was obtained for the wearing power of the eight surfaces, and furthermore, the effects of any change in atmospheric conditions were eliminated. The results are given in Table V.

Table V

Mean Breaking Load before Abrasion = 166·5 lb.

Section No	1	2	3	4	5	6	7	8
Breaking load after abrasion, lb.	70·7	89·0	73·3	105·4	76·9	30·2	63·1	72·7

The commercial silicon carbide abrasive cylinders used in this machine did not exhibit perfectly uniform "textile" abrasive properties at all parts of the testing surface. The following variable factors were assumed to account for this—

(1) Density of structure.
(2) Orientation of plates and needle-shaped grains.
(3) The "finish" or dressing of the grinding surface by the manufacturer.

The manufacturers stated that the density might be expected to vary slightly in the particular cylinder(s) tested especially between opposite ends of one diameter.

Splinters or needle-shaped grains, also plate-like grains, would show a tendency to set themselves lengthwise at right-angles to the direction of the compacting force during manufacture, which in this case was perpendicular to the axis of the cylinder.

The grinding faces of the cylinders were given a commercial finish by the makers by means of the usual dressing tool. It is quite possible for this to leave an uneven finish from the point of view of testing cloth with a non-rotating cylinder. We are advised that special methods could be developed in manufacture to give practically uniform distribution of density and abrasive properties.

THE RE-DESIGN OF THE CROSS-HEAD

In view of the above results the cross-head carrying the cylinder was re-designed to accommodate a larger cylinder and at the same time to allow it to revolve a small amount at the end of each complete traverse.

Two ratchets with their teeth in opposite directions are fixed on one side of the roller shaft and are operated upon by catches. At one end a catch is fixed to the cross-head and acts permanently on the ratchet, so preventing the cylinder from revolving in one direction. At the other end a catch with

a long arm is fulcrumed on the lowest portion of the cross-head and so prevents the roller from revolving in the other direction. Normally, therefore, the two catches hold the cylinder firm and cause it to wear the cloth; but when the cross-head approaches the front of the machine the latter catch is acted upon by the stop on the bed-plate and lifted clear of the ratchet so that the cylinder can revolve a little. When, however, the cross-head reverses, the cylinder is prevented from moving back into its original position by the catch at the opposite side of the roller.

It should also be observed that when carrying out the preliminary trials of the new cross-head it was found possible to wear out the sample sufficiently quickly without the aid of the ridge on the base plate. The latter was, therefore, dispensed with. It was also found that by suitably adjusting the ratchets and pawls a small strip of cloth at about the centre of the traverse was worn when the cylinder was travelling both backwards and forwards whilst the other portions were worn only when the cylinder was travelling in one direction. In this way the more intense wear was concentrated as had hitherto obtained.

With this ratchet and pawl device the cylinder was made to revolve slightly at the end of every complete traverse and expose a fresh surface to the cloth. Thus by arranging the number of rubs in every test so that the cylinder made a number of complete revolutions, the variations in the abrasive properties of the various portions of the cylinders' surface averaged out.

THE VARIATION IN ABRASIVE POWER FROM CYLINDER TO CYLINDER

The next experiment was carried out to discover what kind of variation in the abrasive power existed among a number of "Carborundum" cylinders, and for this purpose six such cylinders all designated 60K were used on samples from the same piece of cloth. The usual order of Rotary sampling was adopted, and the wearing power of each cylinder determined by allowing it to act for 100 rubs on each of ten samples. The results which are given in Table VI show what a wide variation was found to exist. While the samples rubbed by cylinder No. 1 had a mean strength of 82·4 lb., those acted upon by cylinder No. 4 had a mean strength of only 50·4 lb.

Table VI

Mean Breaking Load before Abrasion 172·6 lb.

Roller No.	1	2	3	4	5	6
Breaking load after abrasion, lb.	82·4	73·2	67·2	50·4	80·3	69·5

A further supply was then obtained from the Carborundum Company Ltd. of six cylinders which had been specially processed and finished in order to obtain as far as possible a similar surface on each. These were tested in the same way as before, and the results were as shown in Table VII.

Table VII

Mean Breaking Load before Abrasion = 172·6 lb.

Roller No.	1	2	3	4	5	6
Breaking load after abrasion, lb.	72·9	73·0	52·2	79·9	77·1	80·8
P. E. of means ±	3·3	3·0	0·9	3·0	2·1	3·4

It will be observed that five out of the six rollers possessed similar abrasive properties, which was an improvement on the previous test; but the figure obtained for roller No. 3 indicated that the production of a standard

abrasive for the purpose of this test might prove a very difficult, if not impossible, problem.

Further trials were then made with abrasives obtained from two other sources—six rollers of "Crystolon" 60J from the Norton Company, and six rollers of "Hy-tens" 60J from the Precision Grinding Company. Twelve tests were made with each roller, the results obtained being as follows—

Table VIII

Mean Breaking Load before Abrasion 189 lb.

Roller No.	1	2	3	4	5	6
Breaking load after abrasion, lb						
"Crystolon" 60J (200 rubs) ...	136·3 ±1·52	136·6 ±2·00	134·3 ±2·49	131·9 ±1·78	137·1 ±1·95	144·3 ±1·85
"Hy-tens" 60J (150 rubs) ...	77·8 ±2·25	77·1 ±1·98	70·3 ±1·77	69·1 ±2·48	72·8 ±1·52	66·1 ±2·11

The highest value was 12·4 lb. greater than the lowest in the case of the "Crystolon" 60J, and 11·7 lb in the case of the "Hy-tens" 60J. The latter evidently produces more rapid wear, for both sets of rollers were tested on the same cloth.

Although these last series of tests showed a marked similarity between the rollers in their respective sets, it nevertheless seems to us that the uniformity obtained is not sufficiently near to perfection to warrant the adoption outright of a standard abrasive. Furthermore, each lot of rollers were made at the same time, and therefore might be expected to give more uniform results than rollers turned out from different batches at intervals of several months.

It is, therefore, concluded that, if the kind of wear test dealt with in this paper can ever be adopted as a standard test, and if machines are to be obtainable which will all give comparable results, then it will be necessary to test every abrasive cylinder against a single standard and discard as unsuitable all that differ from it by more than some fixed and narrow margin. This would, of course, necessitate a thorough investigation of the consistency over a very long period of the abrasive power of any material from which the standard is to be made, for although it has been already shown that with a "Carborundum" cylinder no change took place over a total period of 10 hours' use, the standard would have to be used for a very much greater length of time than that.

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5—RANDOM AND SYSTEMATIC SELECTIONS OF WARP SPECIMENS IN CLOTH SAMPLING

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SUMMARY

This note discusses the relative merits of systematic and random methods of selecting warp specimens from a sample of fabric, when both selections are made on the Latin-square principle. Reasons are given for the belief that the distribution of specimens in the fabric itself is already random, so that the random selection would only show to advantage in the particular case of the random distribution where the specimens were arranged periodically, and where, moreover, the periodical selection by the systematic method happened to coincide with the periodical arrangement. A comparison of the methods of sampling is made in the case of three fabrics—two cottons and one linen; from each of these fabrics 256 warp specimens had been taken, 16 from each of 16 adjacent warp strips, and tested for strength; an analysis of the strength-values shows that, for these three fabric samples, the random selection does not lead to any better results than the systematic, thus supporting the conclusion arrived at from purely general considerations. At the same time it is recognised that from a purely theoretical point of view the random method of selection retains its superiority, and that it is therefore better to adopt the random method unless there are cogent practical reasons for adopting the systematic method.

I—INTRODUCTION

In the course of his valuable paper on the application of modern statistical methods to textile research, Tippett criticises a sampling arrangement used by myself in the determination of the strengths of fabrics at different humidities. Tippett maintains that "the question of the sampling of cloths . . . . is analogous to the problem of arranging experimental plots for agricultural field trials . . . . . *it is to be expected that there will be systematic regional variations of strength,** on which will be superimposed the smaller random variations, and that by a suitable arrangement, only these random variations will contribute to the inaccuracy of the comparisons."[1] He asserts that systematic arrangements, such as that used by me, "violate one of the conditions that must be satisfied if reliable estimates of probable errors or variances are to be made—the treatments are not randomly distributed within the restrictions imposed to eliminate regional variations."[1] He points out that the best arrangement, if circumstances permit, is that of a Latin square combined with a random distribution of specimens within the square. He admits that "there are disadvantages to the method, however, and precautions are necessary . . . . . Mistakes are more liable to be made in random than in systematic arrangements, but within the restrictions imposed randomness is essential if accurate estimates of the errors of sampling are to be made; *regular arrangements of treatments may often coincide with some uneliminated trend in the cloth.*"*[2]

With reference to this criticism I may point out that, as explained in my paper,[3] the experimental work was mostly carried out in 1918, so that the sampling was necessarily done some years before the publication of

*Italics are mine—A.J.T.

Fisher's work in which he explains the Latin-square method of sampling and the importance of randomness therein.[4] Nevertheless, the criticism holds good of course, if its basis is sound. But while it may be indisputable that the random Latin-square method of selection is theoretically superior, it may be questioned whether the matter is really of any great practical importance in the case of comparatively small samples of textile fabrics, and whether it is legitimate to draw an analogy between cloth-sampling and agricultural field-trials. As to the latter, Fisher refers to the effect of "some physical feature of the field such as the ploughman's 'lands,' which often produce a characteristic periodicity in fertility due to variations in depth of soil, drainage, and such factors."[5] Tippett similarly maintains that "regular arrangements of treatments may often coincide with some uneliminated trend in the cloth."[2] What is the justification for this statement ? Is it a conclusion based on experimental facts or does it rank merely as an hypothesis ? And are we to infer that my method of sampling was such that my test-results, and the conclusions drawn from them, are to be regarded as untrustworthy ?

As it happens, when arranging for the sampling in my series of tests, I did consider certain alternatives before adopting my particular arrangement, though all the alternatives were of a semi-systematic type. I finally adopted my particular semi-systematic arrangement because I could see no reason from a practical standpoint why any one of the alternatives would be likely to give a more satisfactory distribution. Now, before proceeding further, it must be made perfectly clear what is the particular danger to be apprehended in the systematic selection of test-specimens. In its extreme form it is this—that there may be some *periodically-occurring* strong or weak places in the fabric, and that the systematic periodical selection of test-specimens may happen just to coincide with the periodical distribution of the strong or weak places; a *systematic fall or rise* in the strength either across or along the warp would not cause the systematic arrangement of test-specimens to give any worse result than the random arrangement. It should be noted that even if there should be a *periodic* occurrence of strong or weak places, it would not affect the result unless the periodic selection of test-specimens coincided in some measure with this periodicity. Looking at the method statistically, therefore, we may ask two questions— first, what are the chances of occurrence of a periodic distribution of strong or weak places; and secondly, what are the chances that the periodic systematic selection of test-specimens will coincide with the periodic distribution of strong or weak places ? To answer these questions we will first consider how the warp of a fabric is prepared, and afterwards we will see what light is thrown on them by some test results for three different fabrics.

II—GENERAL THEORETICAL CONSIDERATIONS

(1) Correlation between Parallel Warp Strips

Normally, the yarn is wound from a number of cops or bobbins successively on to a warper's bobbin; a number of these warper's bobbins are placed in a creel and the yarn drawn off from them to form the warp. It is evident, therefore, that the arrangement of the thick and thin places in contiguous portions of the neighbouring yarns is as nearly random as could be imagined. In a warp consisting of some 3000 or 4000 threads there is no reason to expect the strong or the weak places to come together in neighbouring yarns, except in the degree that would be expected from a random arrangement. This

is not to say that strong and weak areas will not occasionally be met with; on the contrary, a random selection of variable elements such as yarns must inevitably lead to the existence of such areas, but they will not occur periodically more often than would be expected from a random arrangement. Evidently, therefore, the arrangement across the warp is an ideal random arrangement, and no correlation should exist between the strengths of contiguous portions of neighbouring warp strips.

(ii) Correlation along Individual Warp Strips

Along the warp the situation is rather more complicated owing to the correlation that exists between the strengths of successive short lengths of a single yarn. If strong and weak lengths alternated regularly, then the strength of specimens in a warp strip would repeat at intervals; if the periods were the same for each yarn, then the periodicity for the strength of the warp strips would be the same as for any of the yarns; but if the periodicities of the various yarns were different, the periodicity of the warp strip would be equal to the lowest common multiple of the periods of the several yarns. Whether the strengths of successive lengths of a warp strip will be correlated with one another turns therefore on the regularity and the length of the period in the yarns. Seeing that the length of test-specimen of the warp strip used in my tests was 9 inches, it is clear that we can omit from consideration any periodicities in the yarn of less than this length; moreover, we may use test-results on successive yarn-specimens of 12 inches length as a guide to the occurrence of periodicities in the yarn. On examining such test results we find that even in a single yarn the maxima and minima strengths occur at very irregular intervals. It follows, therefore, that when a number of such yarns are combined together to form a warp strip, we should not expect any regular periodicity in the occurrence of maxima and minima values in the strengths of successive lengths of this strip; moreover, it follows that there should be but little correlation between the strengths of successive short lengths of a warp strip. It is of course conceivable that under exceptional circumstances a yarn may be spun which has a regular periodicity in the occurrence of strong and weak places. But the probability of such a yarn occurring, and of a large number of bobbins of such a yarn being spun, must be very small indeed; and if we refer to the second question, viz. the chances that the periodic systematic selection of test-specimens will coincide with the periodic distribution of strong or weak places, we must conclude that the chances of this coincidence are so remote as to have been negligible in my tests, for in these tests only two test-specimens of each kind were selected from each warp strip. These two specimens were at $4\frac{1}{2}$-feet intervals, so that the only danger to be apprehended is that all the yarns in the strip had a regular periodicity of $4\frac{1}{2}$, $2\frac{1}{4}$, or $1\frac{1}{8}$ feet. Even if this happened it would only mean that each of the specimens in a warp strip was duplicated in the same strip; there would still remain a random distribution of specimens of each kind in the 10 different strips. In these circumstances it appears that the probability of strong and weak places having occurred with a periodicity which coincided with the periodic selection of test-specimens by the given systematic method may be regarded as having been so small as to be absorbed in the ordinary chances of random sampling.

(iii) Cards Analogy

It appears therefore that the arrangement of warp specimens in a fabric may be likened to the random selection of cards with different numbers written on them, the numbers on the cards representing the strengths of

individual specimens; the cards may be arranged in order of selection to form rows and columns, thus representing the arrangement of specimens of different strengths. If we now arrange the cards in any given number of heaps, say four, it will not matter how we select them if we do it without regard to the numbers written on them, and the original selection was unbiassed. The "systematic" and "random" methods of selection will both be secondary selections, and, so far as the original material is concerned, both will be random selections. The sampling might be made more complex by filling up rows and columns at random on selecting cards at random from the original material; and if they now be made into four heaps by "systematic" and "random" selections, they will both be tertiary selections, and both will be random as far as the original material is concerned.

Alternatively we may regard the matter as analogous to the shuffling of a series of cards. If the cards are well shuffled, they will be in a random order; and a second or third shuffle, while it will lead to a different order, will not improve the randomness. And to insist that it is wrong to make a systematic selection of test-specimens from what I believe to be a randomly arranged group of specimens in a sample of fabric, is like a card-player insisting that in the dealing of a hand the cards should be dealt to the four players not in rotation, but at random.

III—EXPERIMENTAL RESULTS

(i) Material and Testing

In view of the importance of the sampling, and of the desirability of testing practically the different methods of selecting the specimens, during the same year that the humidity-strength tests were carried out I had some sampling tests made on the three fabrics which were most exhaustively studied in the humidity-strength tests. The three fabrics in question were the cotton fabrics E^6 and F^6, and the linen fabric P^7; all three fabrics were 4 oz. fabrics, E being a plain-scoured cotton, F a plain mercerised cotton from twofold yarns, and P a plain unbleached linen. Full details of these fabrics are given in the original paper. Each of these fabrics was over 36 inches wide and was divided so as to yield 16 warp strips each 2 in. wide after fraying down the edges; each of these warp strips was 3 yards long, so that it yielded 16 specimens each 9 inches long. Each specimen was marked so as to show the exact position in the fabric from which it had been taken. All specimens were then tested wet after immersion in water for a long period so as to ensure complete saturation.

(ii) Results of Tests

The results obtained for the strengths of the specimens of the three fabrics are given in Tables I, II, and III, in which the strength of each 2-inch specimen is given in pounds and shown in the table in the position occupied by the specimen.

(iii) Distribution of Strong and Weak Places

We will first consider certain simple methods of treating the results given in Tables I, II, and III. Below each original square A are given, in B, the results when combined in successive pairs in any one warp strip; in this way the 16 values in each warp strip are reduced to 8 values, each of which represents a successive pair in the original. We may now repeat the process and thus obtain, in C, 4 values for each strip, each of which therefore represents the sum of the values of four successive specimens in the original strip. Repeating the process once more we obtain, in D, 2 values one of which represents the sum of the values of the 8 specimens in the first

half of the strip, and the other represents the sum of the values of the 8 specimens in the second half of the strip. Lastly, by combining these two values we obtain, in E, the sum total of the values of the 16 specimens comprising the warp strip. By inspection of the totals in the last line of each table it is a simple matter to compare the strengths of each warp strip taken as a whole; and by working upwards from the bottom line it is easy to locate the position of the particularly strong or weak specimens in each strip. Thus section D helps us to see whether the weak specimens are in the top half or in the bottom half of the strip; and then proceeding to section C we can note whether the weak specimens are in any particular quarter of the strip and so on, until we arrive at the original results, from which we can appreciate the influence of the individual specimens.

If instead of combining the results of successive specimens as in proceeding from section B to section C, we combine the results for adjacent specimens, we then obtain the square F. By combining the results in this square in sets of four, taking adjacent and successive pairs together, we obtain square G; again combining the results of square G in sets of four, taking adjacent and successive pairs together, we obtain square H; and adding together the four results in square H we get the grand total of all the observations.

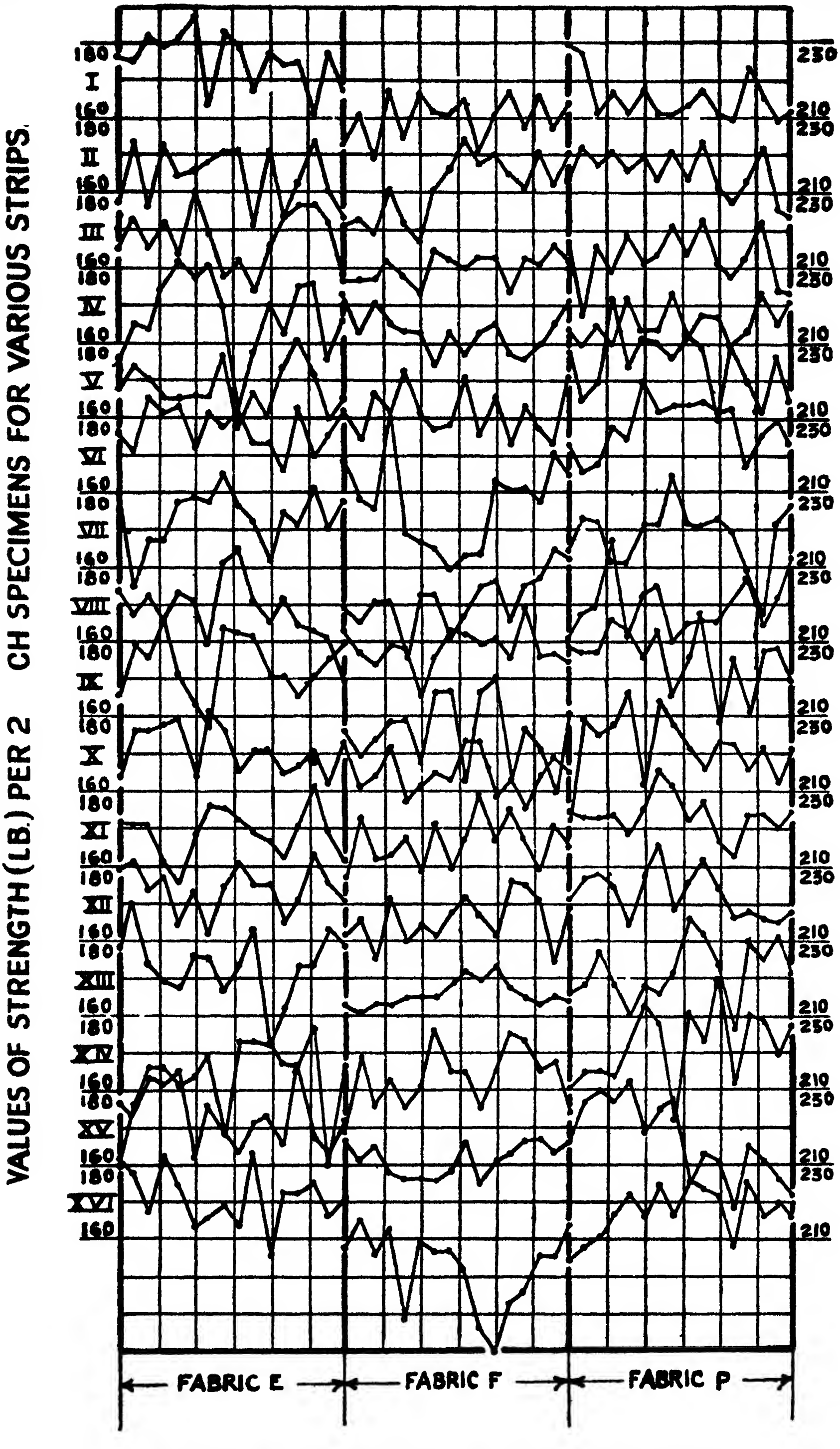
If these tables be examined, it will be found that the results are in fact irregularly distributed; there appears to be no regular periodicity either across the strips or along the strips. The absence of any regular periodicity is also apparent from Figs. 1 and 2, in which are plotted the original values, showing the variation of strength along and across the warp strips of each of the three fabrics.

If we next refer to the various reduced squares we find that there are marked differences between the different plots in each square; this of course is to be expected as a consequence of the irregularity of the material itself. But as we pass from the smaller squares to the larger squares there is nothing to show that the differences between the plots, and ultimately between the test-results for individual specimens, repeat periodically and regularly.

In each of the 8-side squares (F) the results have been classified as weak, medium, or strong. The limits which have been applied to designate the different regions of the fabrics as weak, medium, or strong, are shown in the table below, the figure in brackets indicating the number of values falling in the given class.

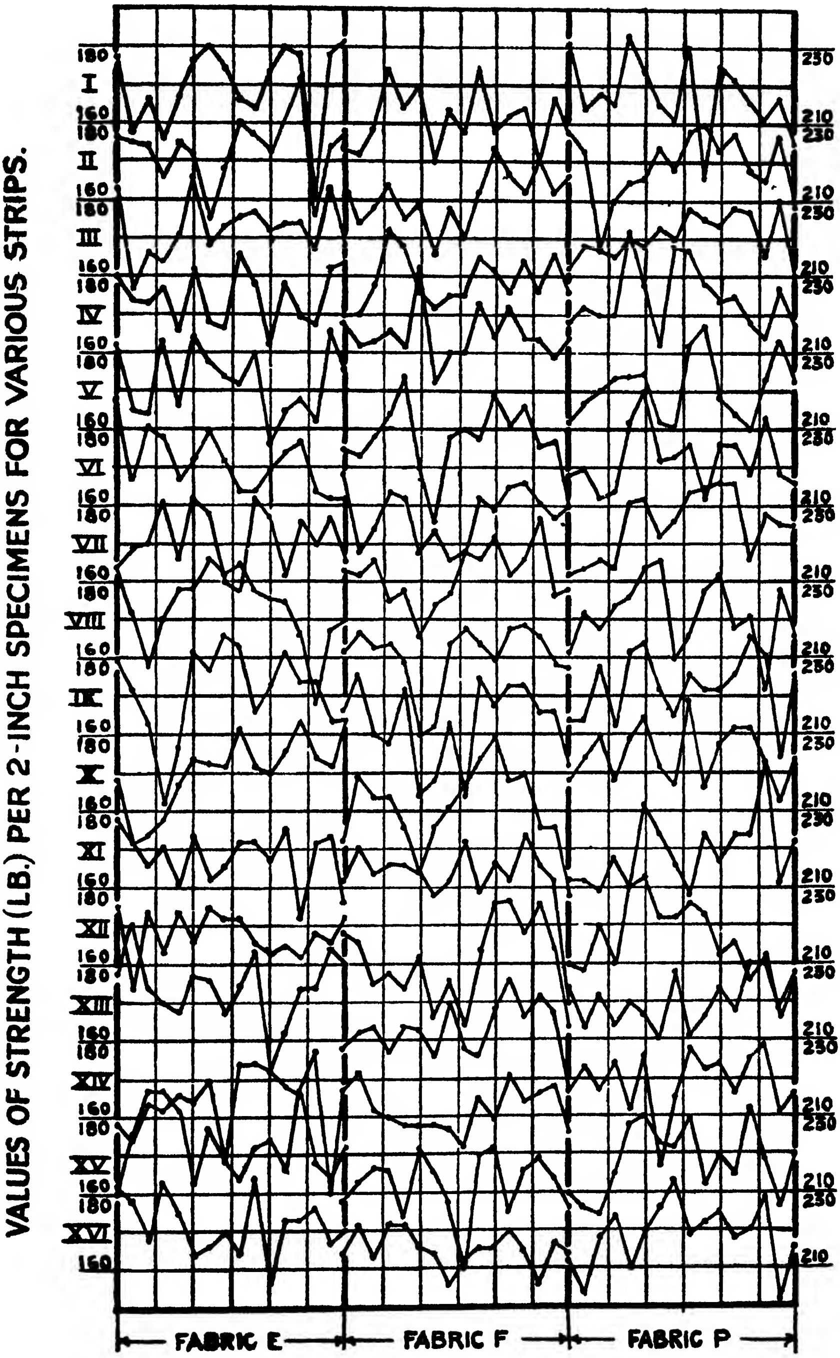
	Weak	Medium	Strong
Fabric E	Below 678 (10)	678 to 699 (35)	Above 699 (19)
Fabric F	Below 631 (15)	631 to 659 (32)	Above 659 (17)
Fabric P	Below 861 (11)	861 to 899 (37)	Above 899 (16)

If the 8-side squares be examined, it will be seen that in only one case is there any semblance of strong or weak patches running diagonally across the fabric; this is for fabric E, where there seems to be a tendency for strong patches to run diagonally from the top left-hand corner. In such a case we get what corresponds to a periodic arrangement of strong specimens; but even in this case the systematic selection of samples would only break down if the periodic selection coincided with the periodic distribution of the samples. Moreover, a further condition would have to be satisfied, viz.



VARIATION OF STRENGTH ALONG WARP STRIPS.

FIG. 1



VARIATION OF WARP STRENGTH ACROSS WARP.

FIG. 2

Table I

Warp-strength Values of Fabric E

A	177 176 183 180	158 175 157 174	166 174 166 173	156 166 164 177	167 175 171 166	176 172 186 182	180 155 168 168	174 168 173 166	166 180 176 186	164 177 177 178	173 172 172 162	180 182 174 178	178 191 174 170	140 156 167 167	178 174 184 182	182 178 168 183
	182 188 164 184	165 167 169 172	164 181 170 158	183 178 181 170	166 167 166 178	184 172 182 178	178 180 178 186	174 172 160 182	172 164 158 185	180 164 182 178	156 169 177 176	165 174 162 175	168 177 176 167	162 164 170 148	186 162 177 168	175 164 166 170
	180 168 178 175	172 152 172 154	163 154 166 174	142 158 171 163	157 167 161 174	182 174 174 166	177 173 162 175	186 172 166 172	183 182 172 172	166 172 172 166	173 170 168 163	182 176 176 165	174 184 152 162	174 174 172 168	164 172 174 166	164 184 156 173
	176 162 178 168	163 175 161 154	178 178 173 158	176 177 156 167	182 172 160 165	184 170 166 182	172 182 171 178	165 164 162 150	166 172 176 179	168 172 162 173	171 182 170 162	172 184 176 172	174 174 184 180	166 177 140 167	187 168 164 172	173 176 167 170
B	353 363	333 331	340 339	322 341	342 337	348 368	335 336	342 339	346 362	341 355	345 334	362 352	369 344	296 334	352 366	360 351
	370 348	332 341	345 328	361 351	333 344	356 360	358 364	346 342	336 343	344 360	325 353	339 337	345 343	326 318	348 345	339 336
	348 353	324 326	317 340	300 334	324 335	356 340	350 337	358 338	365 344	338 338	343 331	358 341	358 314	348 340	336 340	348 329
	338 346	338 315	356 331	353 323	354 325	354 348	354 349	329 312	338 355	340 335	353 332	356 348	348 364	343 307	355 336	349 337
C	716 718 701 684	664 673 650 653	679 673 657 687	663 712 634 676	679 677 659 679	716 716 696 702	671 722 687 703	681 688 696 641	708 679 709 693	696 704 676 675	679 678 674 685	714 676 699 704	713 688 672 712	630 644 688 650	718 693 676 691	711 675 677 686
D	1434 1385	1337 1303	1352 1344	1375 1310	1356 1338	1432 1398	1393 1390	1369 1337	1387 1402	1400 1351	1357 1359	1390 1403	1401 1384	1274 1338	1411 1367	1386 1363
E	2819	2640	2696	2685	2694	2830	2783	2706	2789	2751	2716	2793	2785	2612	2778	2749

686	662	690	677	687	707	665	712
694	680	705	675	717	686	678	717
702	706	689	704	680	664	671	687
689	679	704	706	703	690	661	681
672	617	680	708	703	701	706	684
679	674	675	675	682	672	654	669
676	709	708	683	678	709	691	704
661	654	673	661	690	680	671	673

2722	2747	2797	2772
2776	2803	2737	2700
2642	2738	2758	2713
2700	2725	2757	2739

G

11048	11006
10805	10967

H

Table II

Warp-strength Values of Fabric F

A	153	152	158	174	164	170	150	164	158	174	158	162	164	150	167	158
	162	154	158	164	155	159	146	158	150	162	174	167	162	170	162	166
	150	150	158	172	168	156	152	155	155	165	162	156	164	156	166	156
	168	162	163	166	162	182	152	160	160	173	164	172	164	164	159	164
	155	153	158	164	174	150	136	158	160	158	169	161	166	156	157	140
	168	148	154	164	162	148	154	146	148	162	159	165	166	161	157	160
	163	162	166	155	158	146	154	157	168	166	172	162	166	177	157	158
	162	167	163	164	159	140	142	164	168	164	160	168	169	166	159	158
	166	176	161	158	172	144	148	163	144	175	168	173	173	166	167	152
	152	169	164	164	156	144	156	161	167	174	180	168	170	156	156	138
	162	171	164	166	166	164	158	162	172	159	167	162	174	166	162	130
	168	166	155	158	154	162	146	156	144	164	176	177	168	176	164	144
	158	162	164	157	164	163	156	170	158	156	168	176	166	174	167	147
	167	172	162	160	158	158	158	157	152	165	159	171	164	166	168	156
	158	163	167	166	154	172	166	158	140	170	172	155	166	169	164	156
	165	172	163	172	172	166	164	156	162	166	166	170	165	156	167	164
B	315	306	316	338	319	329	296	322	308	341	332	329	326	324	329	324
	318	312	321	338	330	338	304	315	315	338	326	328	328	320	325	320
	323	301	312	328	336	298	290	304	308	320	328	326	332	317	314	300
	325	329	329	319	317	286	296	321	336	330	332	330	335	343	316	316
	318	345	325	322	328	288	304	324	311	349	348	341	343	322	323	290
	330	337	319	324	320	326	304	318	316	323	343	339	342	342	326	274
	325	334	326	317	322	321	314	327	310	321	327	347	330	340	335	303
	323	335	330	338	326	338	330	314	302	336	338	325	331	325	331	320
C	633	618	637	676	649	667	600	637	623	679	658	657	654	644	654	614
	648	630	641	647	653	584	586	625	644	650	660	656	667	660	630	616
	648	682	644	646	648	614	608	642	627	672	691	680	685	664	649	564
	648	669	656	655	648	659	644	641	612	657	665	672	661	665	666	623
D	1281	1248	1278	1323	1302	1251	1186	1262	1267	1329	1318	1313	1321	1304	1284	1260
	1296	1351	1300	1301	1296	1273	1252	1283	1239	1329	1356	1352	1346	1329	1315	1187
E	2577	2599	2578	2624	2598	2524	2438	2545	2506	2658	2674	2665	2667	2633	2599	2447

F	621	654	648	618	649	661	650	653
	630	659	668	619	653	654	648	645
	624	640	634	594	628	654	649	614
	654	648	603	617	666	662	678	632
	663	647	616	628	660	689	665	613
	667	643	646	622	639	682	684	600
	659	643	643	641	631	674	670	638
	658	668	664	644	638	663	656	651

2564	2553	2617	2596
2566	2448	2610	2573
2620	2512	2670	2562
2628	2592	2600	2615

G

10131	10396
10352	10453

H

Table III

Warp-strength Values of Fabric P

A	231	214	218	215	233	224	215	211	230	196	225	222	216	211	217	205
	228	223	198	210	215	216	224	218	228	230	223	227	218	215	227	208
	212	218	217	215	220	218	223	220	228	225	223	228	227	215	230	210
	218	222	210	210	242	228	212	238	237	228	224	225	218	214	227	217
	212	217	220	223	224	225	212	211	232	237	218	214	210	223	233	222
	218	220	212	214	232	240	222	223	226	212	226	226	218	233	218	216
	212	214	216	214	231	232	222	226	234	235	236	236	216	228	225	225
	212	222	218	224	226	234	236	210	216	228	232	218	221	202	228	216
	214	214	228	212	232	234	222	215	226	222	222	226	236	231	204	226
	218	224	230	218	229	235	222	217	239	216	228	232	232	223	213	224
	212	212	209	218	210	232	224	216	208	224	217	224	224	240	211	222
	210	208	220	210	230	233	222	222	226	223	212	216	206	212	198	208
	224	213	222	214	220	217	210	228	211	216	224	218	230	231	216	226
	216	223	217	224	212	226	197	215	228	222	224	216	225	229	211	216
	210	206	204	215	228	230	223	222	229	212	220	215	232	219	206	220
	212	204	218	224	210	220	226	233	219	222	225	218	220	229	202	216
B	459	437	416	425	448	440	439	429	458	426	448	449	434	426	444	413
	430	440	427	425	462	446	435	458	465	453	447	453	445	429	457	427
	430	437	432	437	456	465	434	434	458	449	444	440	428	456	451	438
	424	436	434	438	457	466	458	436	450	463	468	454	437	430	453	441
	432	438	458	430	461	469	444	432	465	438	450	458	468	454	417	450
	422	420	429	428	440	465	446	438	434	447	429	440	430	452	409	430
	440	436	439	438	432	443	407	443	439	438	448	434	455	460	427	442
	422	410	422	439	438	450	449	455	448	434	445	433	452	448	408	436

C	889	877	843	850	910	886	874	887	923	879	895	902	879	855	901	840
	854	873	866	875	913	931	892	870	908	912	912	894	865	886	904	879
	854	858	887	858	901	934	890	870	899	885	879	898	898	906	826	880
	862	846	861	877	870	893	856	898	887	872	893	867	907	908	835	878
D	1743	1750	1709	1725	1823	1817	1766	1757	1831	1791	1807	1796	1744	1741	1805	1719
	1716	1704	1748	1735	1771	1827	1746	1768	1786	1757	1772	1765	1805	1814	1661	1758
E	3459	3454	3457	3460	3594	3644	3512	3525	3617	3548	3579	3561	3549	3555	3466	3477

F	896	841	888	868	884	897	860	857
	870	852	908	893	918	900	874	884
	867	869	921	868	907	884	884	889
	860	872	923	894	913	922	867	894
	870	888	930	876	903	908	922	867
	842	857	905	884	881	869	882	839
	876	877	875	850	877	882	915	869
	832	861	888	904	882	878	900	844

3459	3557	3599	3475
3468	3606	3626	3534
3457	3595	3561	3510
3446	3517	3519	3528

G

14090	14234
14015	14118

H

that the strong patch would not be sufficiently extensive to provide specimens for the whole set required for each of the different conditions of testing. Neither of these conditions is actually fulfilled by fabric E, for the diagonal arrangement is in fact decidedly irregular, and moreover, in almost every case the strong patch is sufficient to provide at least 6 warp specimens both across and along the warp.

(iv) Correlation of Strengths of Successive Specimens in Warp Strips

We will next ascertain how far there exists any correlation between the strengths of successive specimens in any one warp strip. By comparing the strength-value of each specimen in a strip with that of the succeeding specimen, we obtain 15 pairs of values from which to find the correlation-coefficient for the particular warp strip. Table IV shows the correlation-coefficients for each of the 16 warp strips of the fabrics E, F, and P.

Table IV
Correlation-Coefficients for each of the 16 Warp Strips of the Fabrics E, F, and P

Warp Strip	Fabric E	Fabric F	Fabric P
1	−0·207	−0·538	0·228
2	−0·298	0·571	0·032
3	0·203	0·018	0·018
4	0·301	0·207	−0·254
5	−0·029	−0·432	−0·208
6	−0·109	0·355	0·364
7	0·094	0·289	0·227
8	0·308	−0·002	−0·177
9	0·170	0·244	−0·223
10	−0·108	−0·065	−0·268
11	0·327	−0·347	0·280
12	0·052	−0·112	0·203
13	0·128	0·641	0·139
14	−0·127	−0·061	−0·167
15	−0·029	0·361	0·507
16	0·252	0·393	0·166

Evidently these correlation-coefficients are exceedingly variable. If the correlations were not real but merely a consequence of sampling fluctuations, out of many samples of 15 pairs we should expect one in 10 to have a correlation as high as 0·4409, 1 in 20 as high as 0·5139, 1 in 50 as high as 0·5923, and 1 in 100 as high as 0·6411. Hence, out of 16 correlation-coefficients for each fabric, we should expect one—and only one —to be as high as 0·5. In actual fact, this does occur for fabric P, but for fabric E not one of the values is so high, while for fabric F three of the values attain this magnitude. The discrepancies in the last two cases may be traced to the correlation-coefficients being few in number, for we cannot expect the distribution of 16 correlation-coefficients to be exactly the same as that of a very much larger number. But if we consider the 48 results together, we see that the numbers of correlation-coefficients of the higher values almost exactly correspond with those expected from the odds applicable in each case. That the distribution of the correlation-coefficients is that of chance, is further borne out by the fact that the coefficients are equally positive and negative (8 of each) in the case of fabrics E and F, and practically so (9 positive and 7 negative) in the case of fabric P. Hence we may conclude that there is no reason to fear that, in these fabrics, systematic sampling of warp strips will be vitiated by the occurrence of a regular wave-form distribution of strength within the strips.

(v) Comparison of Means of Random and Systematic Latin-square Arrangements for Four Treatments

We will now imagine that we select sets of specimens according to some particular system of sampling, as we would do in order to investigate the effect of different conditions of humidity. But instead of testing these sets under different conditions, we actually tested them all under the same conditions, so that we can ascertain what errors would have been present in the means owing to the sampling alone. It will be observed that for each of the three fabrics the number of specimens was 16 both across and along the warp; thus their strength values form a square of side 16, and this square can be divided into four squares containing 64 values each, or into 16 squares containing 16 values each. They thus form very suitable material for selecting specimens by the Latin-square method, and we will accordingly use it by comparing the results given by Latin-square selections which are completely randomised with those which are completely systematic.

In the first place we will confine our attention to four sets of conditions, for which we therefore select four groups each containing 64 specimens. We will denote the different conditions by A, B, C, and D, and we will apply these letters respectively to the four sets of specimens to be tested under the conditions represented by the respective letters. Now a Latin-square appropriate for four conditions of testing will contain 16 individual specimens. Hence, in arranging for the selection of our samples according to the random Latin-square arrangement, we need 16 different Latin-squares to include the whole 256 values for each fabric. We will also imagine that the samples are selected according to a completely systematic Latin-square arrangement with the same systematic arrangement repeated 16 times; we will then compare the results obtained by the two different methods of selection. The random Latin-square arrangement finally adopted is that shown in Fig. 4, and the systematic arrangement in Fig. 3. When all the samples were selected in this way the results given in Table V were obtained for the mean values of the different sets by the two methods of sampling for the different fabrics.

Table V

Set	Fabric E		Fabric F		Fabric P	
	Systematic	Random	Systematic	Random	Systematic	Random
A	171·7	170·6	162·7	161·5	220·6	219·6
B	170·3	171·7	159·9	161·6	221·0	221·8
C	171·0	170·7	161·3	160·9	220·8	220·9
D	171·9	171·8	161·9	161·8	219·7	219·9
Mean of A–D ...	171·2	171·2	161·4	161·4	220·5	220·5
Standard deviation of A–D ...	0·63	0·55	1·02	0·33	0·63	0·85

It will be noticed that from these results there is little to choose between the random and the systematic arrangements. Seeing that A, B, C, and D only nominally represent different treatments or conditions, and that they have actually all been subjected to the same treatment and conditions of testing, it follows that with perfect sampling and a very large number of tests the mean result for each set—A, B, C, and D—should be the same. In point of fact, the results by each method of sampling do agree quite

closely; for fabric E, the maximum difference between any pair is 0·9% (systematic), and 0·7% (random); for fabric F, 1·7% (systematic), and 0·6% (random); and for fabric P, 0·6% (systematic), and 1·0% (random). Obviously, there is little to choose between the results obtained by the two methods of selecting the specimens.

A B C D	A B C D	A B C D	A B C D
B C D A	B C D A	B C D A	B C D A
C D A B	C D A B	C D A B	C D A B
D A B C	D A B C	D A B C	D A B C
A B C D	A B C D	A B C D	A B C D
B C D A	B C D A	B C D A	B C D A
C D A B	C D A B	C D A B	C D A B
D A B C	D A B C	D A B C	D A B C
A B C D	A B C D	A B C D	A B C D
B C D A	B C D A	B C D A	B C D A
C D A B	C D A B	C D A B	C D A B
D A B C	D A B C	D A B C	D A B C
A B C D	A B C D	A B C D	A B C D
B C D A	B C D A	B C D A	B C D A
C D A B	C D A B	C D A B	C D A B
D A B C	D A B C	D A B C	D A B C

FIG. 3—Systematic Latin Squares for 4 Treatments

C D B A	B A D C	D B A C	A C B D
B C A D	C D A B	A C D B	B D A C
A B D C	A B C D	C A B D	D B C A
D A C B	D C B A	B D C A	C A D B
C B A D	D A C B	B A C D	A D B C
A C D B	B C A D	C D A B	D C A B
D A B C	A D B C	A B D C	C B D A
B D C A	C B D A	D C B A	B A C D
D A C B	B D A C	C A B D	A B D C
A B D C	C A B D	B C D A	C D B A
B C A D	D B C A	D B A C	B A C D
C D B A	A C D B	A D C B	D C A B
B C D A	D C A B	A B C D	C B D A
A D C B	C B D A	C D B A	D A B C
C B A D	B A C D	B A D C	B C A D
D A B C	A D B C	D C A B	A D C B

FIG. 4—Random Latin Squares for 4 Treatments.

We may use the results of these tests in another way. We may divide the whole sample of each fabric into four equal sections each containing 64 test-values; this may be done in two ways, first parallel to the warp, and secondly, parallel to the weft; the sections obtained by the former method we shall call "warp sections" and those obtained by the latter method "weft sections." We may now test the difference between the two methods of selection by comparing the four mean values (A, B, C, and D) obtained from each of the four sections in each case. Each mean value is the mean of 16 test-values. The means for the different warp and weft sections are given for each fabric in Table VI.

Table VI

Fabric Selection	Section No.	Warp Sections				Weft Sections			
		A	B	C	D	A	B	C	D
E Systematic	I	170·2	167·9	170·0	169·4	173·3	170·2	174·1	172·2
	II	170·9	173·4	170·2	173·7	172·1	171·5	169·5	175·4
	III	174·1	170·4	170·6	175·4	169·2	171·4	167·8	169·7
	IV	171·6	169·6	173·0	168·6	172·1	168·1	172·4	169·8
E Random	I	169·5	168·2	170·7	169·1	171·9	174·2	172·2	171·6
	II	171·1	170·9	171·6	174·7	170·6	174·1	169·9	173·9
	III	171·6	174·9	171·3	172·7	171·1	167·8	170·8	168·4
	IV	170·1	172·8	169·2	170·7	168·8	170·7	169·8	173·3
F Systematic	I	162·9	161·2	161·1	162·5	163 3	159·7	161·4	161·2
	II	161·0	155·9	155·1	159·6	161·0	157·3	159·2	159·7
	III	164·4	161·3	165·8	164·9	162·8	160·4	162·2	162·2
	IV	162·5	160·1	163·2	160·9	163·7	161·9	162·2	164·7
F Random	I	163·1	160·6	161 3	163·7	161·2	161·1	162·1	161·2
	II	158·4	158·6	158·4	156·1	161·1	160·8	155·6	159·7
	III	163·6	163·1	161·7	168·0	159·6	162·7	163·7	161·8
	IV	161·0	164·0	162·1	159·5	164·2	161·7	162·2	164·4
P Systematic	I	215·6	216·6	218·2	213·9	222·4	217·5	221·0	219·7
	II	224·3	223·0	223·0	221·9	221·4	225·7	221·8	220·8
	III	224·8	224·2	221·6	223·4	221·0	221·9	217·7	222·0
	IV	217·8	220·1	220·4	219·7	217·7	218·8	222·6	216·4
P Random	I	213·2	217·1	217·2	216·9	220·2	219 1	220·4	220·9
	II	222·6	224·7	222·9	221·9	220·9	223·8	223·4	221·5
	III	223·7	224·7	223·7	221·9	221·8	222·1	220·5	218·3
	IV	218·8	220·7	219·6	218·8	215·5	222·3	219·1	218·7

The four mean values for A, B, C, and D respectively, in any one section, do not differ very much from one another. The mean of A, B, C, and D, represents of course the mean of the 64 specimens in any one section, so that the mean of A, B, C, and D, of any one section is necessarily the same for that section whether obtained from the systematic or from the random method of selection. In order to indicate the variabilities of the means of A, B, C, and D, in any one section according to the two methods of selection, Table VII has been compiled; in this table are given the grand mean for each section, and the standard deviations of the mean values of A, B, C, and D, from this grand mean, as obtained by the two methods of selection.

Obviously, since A, B, C, and D represent four sets of 16 specimens each, which have been tested under similar conditions, with a sufficiently large

Table VII

Fabric	Section No	Warp Sections: Grand Mean	Warp Sections: Standard Deviation of Group Means: Systematic	Warp Sections: Standard Deviation of Group Means: Random	Weft Sections: Grand Mean	Weft Sections: Standard Deviation of Group Means: Systematic	Weft Sections: Standard Deviation of Group Means: Random
E	I	169·4	0·90	0·90	172·4	1·46	1·02
	II	172·1	1·52	1·69	172·1	2·04	1·89
	III	172·6	2·18	1·41	169·5	1·29	1·45
	IV	170·7	1·71	1·32	170·6	1·76	1·67
F	I	162·2	0·67	1·27	161·4	1·28	0·41
	II	157·9	2·46	1·03	159·3	1·33	2·19
	III	164 1	1·69	2·35	161·9	0·90	1·51
	IV	161·7	1·23	1·64	163·1	1·14	1·19
P	I	216·1	1·56	1·68	220·1	1·80	0·21
	II	223·0	0·85	1·03	222·4	1·92	1·22
	III	223·5	1·20	1·01	220·7	1·75	1·51
	IV	219·5	1·01	0·77	218·9	2·12	2·51

number of tests and perfect sampling the mean values of A, B, C, and D should be the same. The mean values of Table VI represent only 16 values each, but the number is the same in each case and we may proceed to compare the variabilities of the two methods of sampling by reference to the standard deviations given in Table VII. It will be observed that the standard deviation varies considerably for each set of four sections, warp or weft, of any one fabric; sometimes the standard deviation is less for the systematic than for the random sampling, and sometimes *vice versa*. For fabric E, in two cases the systematic gives a less value than the random and in five cases a greater value; in one case the two methods give equal values. For fabric F, the systematic gives a less value than the random in six cases and a greater

A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A
C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B
D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C
E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D
F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E
G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F
H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G
A	B	C	D	E	F	G	H	A	B	C	D	E	F	G	H
B	C	D	E	F	G	H	A	B	C	D	E	F	G	H	A
C	D	E	F	G	H	A	B	C	D	E	F	G	H	A	B
D	E	F	G	H	A	B	C	D	E	F	G	H	A	B	C
E	F	G	H	A	B	C	D	E	F	G	H	A	B	C	D
F	G	H	A	B	C	D	E	F	G	H	A	B	C	D	E
G	H	A	B	C	D	E	F	G	H	A	B	C	D	E	F
H	A	B	C	D	E	F	G	H	A	B	C	D	E	F	G

FIG. 5—Systematic Latin Squares for 8 Treatments

value in two cases. For fabric P, the systematic gives a less value than the random in three cases and a greater value in five cases. Putting all these results together we find that the systematic gives a less value than the random method in 11 cases and a greater value in 12 cases; in one case the two methods give identical values. It therefore appears that there is practically nothing to choose between the two methods of sampling so far as relates to these three fabrics.

E	H	C	B	D	F	A	G	B	G	H	F	C	E	A	D
B	A	F	G	C	E	H	D	C	A	D	E	H	B	F	G
H	G	E	D	A	C	B	F	D	E	A	B	F	G	H	C
A	F	B	H	G	D	E	C	F	C	G	H	A	D	B	E
D	C	H	A	B	G	F	E	H	B	E	D	G	F	C	A
F	E	G	C	H	A	D	B	G	H	F	A	D	C	E	B
G	B	D	E	F	H	C	A	E	F	C	G	B	A	D	H
C	D	A	F	E	B	G	H	A	D	B	C	E	H	G	F
D	C	H	E	A	B	F	G	A	G	E	F	H	D	C	B
B	A	F	G	E	C	H	D	D	C	F	B	A	G	H	E
G	H	E	C	D	F	A	B	G	E	A	H	D	C	B	F
F	D	B	A	H	G	E	C	B	D	C	G	E	H	F	A
A	F	C	D	G	E	B	H	H	F	B	A	C	E	D	G
H	B	G	F	C	A	D	E	E	H	G	C	B	F	A	D
C	E	D	B	F	H	G	A	F	A	H	D	G	B	E	C
E	G	A	H	B	D	C	F	C	B	D	E	F	A	G	H

FIG. 6—Random Latin Squares for 8 Treatments

(vi) Comparison of Means of Random and Systematic Latin-square Arrangements for Eight Treatments

We will now consider the results when selected so as to represent eight different conditions of testing, for which a Latin square must contain 64 individual specimens; for the whole 256 values we require four different 64-fold Latin squares, as shown in Fig. 6; we compare the results by this method of selection with those obtained by a systematic Latin-square arrangement repeated four times, as shown in Fig. 5. These two methods of selection gave the following mean values of the different sets for the different fabrics.

Table VIII

Treatment	Fabric E		Fabric F		Fabric P	
	Systematic	Random	Systematic	Random	Systematic	Random
A	173·4	170·5	163·8	161·4	220·6	221·8
B	169·8	169·8	159·8	160·4	220·1	222·0
C	172·8	174·2	160·4	162·1	222·5	221·0
D	170·3	172·9	162·8	163·7	220·2	218·6
E	170·0	168·8	161·6	159·9	220·7	218·7
F	170·8	171·9	159·8	159·6	221·9	222·6
G	169·1	171·0	162·0	161·8	219·1	218·9
H	173·3	170·4	161·2	162·4	219·3	220·8
Mean A–H ...	171·2	171·2	161·4	161·4	220·55	220·55
Standard deviation A–H ...	1·60	1·63	1·33	1·30	1·16	1·50

As in the case of the four treatments, so in the case of the eight treatments represented by the letters A–H, the results by each method of sampling agree to a very close degree of approximation. For fabrics E and F the standard deviations from the grand mean are almost identical for the systematic and random treatments, but for fabric P the standard deviation for the random selection is distinctly greater than that for the systematic selection.

If the results for eight treatments are divided into warp and weft strips as in the case of the four treatments, we obtain two warp sections and two weft sections; we may test the difference between the two methods of selection by comparing the eight mean-values A–H (obtained from each of the two sections in each case.) Each mean value is again the mean of 16 test-values. The means for the different warp and weft sections are given for each fabric in Table IX; Table X shows the grand mean for each section, and the standard deviations of the mean values of A–H from this grand mean, as obtained by the two methods of selection.

It will be observed that the standard deviation varies considerably for each pair of sections warp or weft, of any one fabric. For fabric E, the standard deviation is less for the systematic selection than for the random in two cases, equal in a third case, and greater in the fourth. For fabric F the systematic is less than the random in one case, equal in the second case, and greater in the other two cases; for fabric P the systematic is less than the random in three cases and greater in one case. Putting all these results together, we find that the systematic gives a less value for the standard deviation than the random method in six cases, a greater value in four cases, and an equal value in two cases. Again, therefore, the random selection yields no better results than the systematic.

(vii) Comparison of Random and Systematic Latin-square Arrangements by the Analysis of Variance

We will finally compare the different methods of sampling by analysing the sources of variance by Fisher's method,[8] as given by Tippett[9] in his paper. The superiority of this method lies in its revealing how the variation due to the treatment compares with the variation that occurs in the absence of any treatment, and in providing us with a criterion to measure the significance of any difference observed. The results of the analysis are given in Table XI. In this table is included not only the analysis of the variance for the four treatments A, B, C, and D, with the whole bulk of the material arranged in the sixteen 16-fold Latin squares as in Figs. 3 and 4, but also the analysis for 8 different treatments (A to H), with the whole bulk divided up into four 64-fold Latin squares as in Figs. 5 and 6.

Now as no treatments have actually been given to the different sets it follows that in every case the variance of the "treatments" should not be significantly different from that of the residuals, apart from discrepancies arising from the sampling errors. By mere inspection of the mean variances for the different "treatments" and the residuals in each case, it is easy to see that in general no greater accuracy can be claimed for the random than for the systematic method of selection. A more sensitive test is provided by the z method of Fisher,[10] where z is the difference between the natural logarithms of the standard deviations of treatments and residuals respectively. Fisher gives a table showing the levels of significance of different values of z for different numbers of degrees of freedom; the values of z have been

Table IX

Fabric Selection	Section	Warp Sections A	B	C	D	E	F	G	H	Weft Sections A	B	C	D	E	F	G	H
E Systematic	I	171·7	169·8	169·4	168·9	169·4	171·6	170·8	174·3	173·3	171·0	174·1	173·1	172·1	170·8	169·4	174·5
	II	175·1	169·9	176·3	171·6	170·5	170·1	167·4	172·4	173·5	168·7	171·5	167·4	167·8	170·9	168·3	172·2
E Random	I	167·4	169·5	174·6	172·8	169·4	170·6	171·9	169·4	173·8	170·8	175·3	173·7	169·3	174·8	169·4	171·5
	II	173·6	169·9	173·8	173·1	168·1	173·3	170·1	171·5	167·3	168·9	173·1	172·2	168·3	169·1	172·6	169·4
F Systematic	I	164·1	158·6	157·3	162·5	159·8	159·5	158·9	159·6	164·8	158·4	157 4	160·7	159·5	158·4	162·9	160·3
	II	163·5	161·1	163·6	163·1	163·4	160·0	165·1	162·7	162·8	161·3	163·4	164·9	163·7	161·1	161·1	162·1
F Random	I	160·4	159·5	159·3	164·1	157·1	159·2	160·3	160·4	161·1	160·0	160·2	163·7	159·4	159·9	159·0	159·3
	II	162·5	161·3	164·9	163·4	162·6	160·1	163·4	164·4	161·8	160·8	164·0	163·9	160·3	159·4	164·6	165·6
P Systematic	I	219·8	218·4	223·3	216·8	220·1	221·2	218·0	219·0	222·4	220·8	224·9	221·0	221·4	222·4	217·9	219·5
	II	221·4	221·7	221·8	223·5	221·2	222·6	220 1	219·6	218·8	219·3	220 2	219·3	219·9	221·4	220·2	219·1
P Random	I	222·7	219·8	219·6	215·6	216·8	221·3	219·3	221·5	222·7	223·3	222·3	220·1	219·9	222·6	219·3	220·2
	II	220·8	224·1	222·4	221·5	220·6	223·8	218 5	220 2	220 8	220·7	219·8	217·1	217·6	222·5	218·4	221·5

Table X

Fabric Section	Warp Sections Grand Mean A–H	Warp Sections Standard Deviation of Group Means: Systematic	Warp Sections Standard Deviation of Group Means: Random	Weft Sections Grand Mean A–H	Weft Sections Standard Deviation of Group Means: Systematic	Weft Sections Standard Deviation of Group Means: Random
E I	170·73	1·666	2·126	172·30	1·663	2·263
E II	171·66	2·714	1·979	170·09	2·086	2·052
F I	160·03	2·060	1·837	160·30	2 330	1·412
F II	162·81	1·484	1·473	162·54	1·296	2·123
P I	219·57	1·895	2·238	221·28	1·953	1·469
P II	221·50	1·173	1·762	219·79	0·781	1·806

Table XI
Analysis of Variance for Fabrics E, F, and P

Fabric	Source of Variance	Systematic arrangement (16-fold)			Random arrangement (16-fold)			Systematic arrangement (64-fold)			Random arrangement (64-fold)		
		Sum of Squares	Degrees of Freedom	Mean Variance	Sum of Squares	Degrees of Freedom	Mean Variance	Sum of Squares	Degrees of Freedom	Mean Variance	Sum of Squares	Degrees of Freedom	Mean Variance
E	Rows ...	3955·00	48	82·40	3955·00	48	82·40	2372·78	28	84·74	2372·78	28	84·74
	Columns ...	6086·00	48	126·79	6086·00	48	126·79	4486·78	28	160·24	4486·78	28	160·24
	Treatment	88·83	3	29·61	81·77	3	27·26	668·30	7	95·47	686·05	7	98·01
	Residual ...	7992·67	141	56·69	7999·73	141	56·74	11582·92	189	61·29	11565·17	189	61·19
	Total within blocks	18122·50	240	75·51	18122·50	240	75·51	19110·78	252	75·84	19110·78	252	75·84
	Between blocks ...	1517·73	15	101·18	1517·73	15	101·18	529·45	3	176·48	529·45	3	176·48
	Grand total ...	19640·23	255	77·02	19640·23	255	77·02	19640·23	255	77·02	19640·23	255	77·02
F	Rows ...	1991·31	48	41·49	1991 31	48	41 49	1417·45	28	50·62	1417·45	28	50·62
	Columns ...	7020·31	48	146·26	7020·31	48	146·26	5997·70	28	214·20	5997·70	28	214·20
	Treatments	296·26	3	98·75	39·45	3	13·15	454·93	7	64·99	434·12	7	62·02
	Residual ...	5995·18	141	42·52	6251·99	141	44·34	8994·75	189	47·59	9015·56	189	47·70
	Total within blocks	15303·06	240	63·76	15303·06	240	63·76	16864·83	252	66·92	16864·83	252	66·92
	Between blocks ...	2475·22	15	165·01	2475·22	15	165·01	913·45	3	304·48	913·45	3	304·48
	Grand total ...	17778·28	255	69·72	17778·28	255	69·72	17778·28	255	69·72	17778·28	255	69·72
P	Rows ...	4202·44	48	87·55	4202·44	48	87·55	2490·17	28	88·93	2490·17	28	88·93
	Columns ...	5321·94	48	110·87	5321·94	48	110·87	5991·67	28	213·99	5991·67	28	213·99
	Treatments	58·85	3	19·62	195·76	3	65·25	317·21	7	45·32	572·78	7	81·83
	Residual ...	6371·46	141	45·19	6234·55	141	44·22	9933·25	189	52·56	9677·68	189	51·20
	Total within blocks	15954·69	240	66·48	15954·69	240	66 48	18732·30	252	74·33	18732·30	252	74·33
	Between blocks ...	3164·99	15	211·00	3164·99	15	211·00	387·38	3	129·13	387·38	3	129·13
	Grand total ...	19119·68	255	74·98	19119·68	255	74·98	19119·68	255	74·98	19119·68	255	74·98

calculated in every case (for the three different fabrics, four and eight treatments, systematic and random selections), and it was found that even the most extreme differences between the variances of treatments and residuals could not be regarded as significant when this test was applied. Hence we are once more led to the conclusion that for these three fabrics we cannot regard the random arrangement as leading to any better result than the systematic.

In comparing the results of the random and systematic methods of selection we have confined our attention to periods repeating for four or eight specimens. It is of course possible that although there is no repeat with these numbers of specimens there may be with some other number such as 5, 6, or 7. The results could be utilised to test the occurrence of such periods by selecting a portion of the material for the purpose; thus, for a repeat with five specimens we could consider a 15-side square, which could be divided into nine five-side Latin squares, and comprise 225 observations out of the whole 256 available; with six specimens we could use four six-side Latin squares, utilising 144 values; with a repeat for every seven specimens we could use four seven-side Latin squares utilising 196 of the test results. However, from the irregular nature of the curves in Figs. 1 and 2 it is hardly likely that such periods actually occur. Instead of looking for the results of periodicities in this way we could of course analyse the original results across and along the warp to this end; unfortunately, a series of 16 results is far too small to be subjected to periodogram analysis.

IV—CONCLUSIONS

It seems legitimate from all the considerations that have been advanced above to conclude that the test-results of these three fabrics would not have been vitiated by making a systematic instead of a random selection of test-specimens; and further, that so far as my humidity-strength tests were concerned the test-results are not likely to have been seriously aberrant and that the conclusions drawn therefrom must stand. And from the general considerations advanced on pages T78–T80 it appears likely that the same is true for the other fabrics and materials which formed the subject of my tests.

I may add that quite apart from the question of sampling, we have certain other considerations to guide us when judging the reliability of the test-results. In the first place, we have the fact that the strength was determined at a number of different humidities for a number of different fabrics of each class. Now if the test-results had been vitiated by the occurrence of periodicity of strength in the fabric coinciding with the periodicity of the selection of the specimens, it is most unlikely that the relation between strength and humidity would be of a regular nature, not only in one fabric but also in a number of fabrics of the same type. It is true that a few irregularities were in fact found to exist in the strength-humidity curves, but seeing that, in all, 142 such curves were obtained, a certain amount of irregularity in some of these curves must be expected, however perfect the sampling. Another reason for the belief that the results and conclusions are substantially correct is that in the case of each of the unweathered fabrics two sets of specimens were tested under the same set of conditions and, except in four cases out of 56, the results for the two sets were well within the limits which might be expected from the values of the probable errors. It is hardly conceivable therefore that if periodicity had existed, both the first and the

second set of specimens tested under the same conditions would have almost invariably given mean-strength results which were not significantly different from each other.

In all that has been said above it is not implied that the systematic method of selection can in any circumstances be regarded as theoretically superior to the random method of selection; and there can be no question but that the random selection is theoretically the more satisfactory, because it ensures that even if periodicity does occur in a fabric its effects are bound to be avoided. The only question is whether periodicity does in fact occur sufficiently often as to necessitate the taking of special precautions to avoid any disturbance that it might cause. My own belief, based on the reasons previously mentioned, is that the likelihood of such a disturbance is exceedingly small. For simplicity in marking out a fabric there is no doubt that the systematic method has the advantage; the chances of mistakes being made and overlooked in marking out by this method are certainly less than by the random method. It is on practical grounds that Engledow and Yule[11] prefer a systematic arrangement in certain agricultural field trials. But the same practical difficulties are not met with in marking out textile fabrics, and I accordingly conclude that, although it is possible to exaggerate the superiority of the random over the systematic method of selecting fabric test-specimens, yet, unless there are cogent practical reasons for adopting the systematic method, it is better to adopt the random method, and so "make assurance doubly sure."

My thanks are due to Mr. R. Krishna Iyer for his assistance in the considerable arithmetical labour required for this paper.

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6—MONTHLY WOOL GROWTH OF RAMBOUILLET EWES

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INTRODUCTION

The physiological phenomena of wool growth are directly related to the commercial utility of a fleece, for length of fleece is an important character in commercial grading of wool.

For many years the law of diminishing returns (i.e. wool attains two-thirds of its length during its first six months of growth, and the growth steadily diminishes from that point on), has been applied to wool growth, and accepted generally as an accurate statement of fact.

In a study of measurable fleece characteristics in a cross-breeding experiment at the Wyoming Experiment Station, it was observed that fleece characters, length, fineness, and density, were regular rather than spasmodic in their development, if environment and disease were regulated.

Keeping in mind the regularity of development in these fleece characters, it seemed a necessary and logical step to initiate a study of monthly wool growth in various types and breeds of sheep, in order to confirm or contest the idea that wool grows as much as two-thirds of its yearly length during the first six months after shearing.

Consequently, in the spring of 1926, a study of monthly wool growth was inaugurated and carried on for the following four years, using in each breed test six ewes of the following breeds—Rambouillet, Hampshire, Oxford, Corriedale, and Lincoln. All of the common types of wool were represented by these five breeds.

The writer, now studying animal breeding and wool research at Edinburgh University, wishes to express his appreciation for the opportunities and courtesies afforded by the Animal Breeding Research Department during the preparation of this paper. The writer wishes particularly to acknowledge the advice and encouragement extended by Professor F. A. E. Crew, Director of this Department.

REVIEW OF LITERATURE

Rohde, Stohmann, Heyne, Gartner, and Zorn all reported that the growth of wool was much greater during the first six months after shearing than in the succeeding six-month period. These writers' results would uphold the theory of diminishing returns, in that they reported practically no growth during the last two months of the yearly growth, and around two-thirds of its yearly growth attained during the first six months after shearing.

Nordmeyer, in a wool growth experiment with mutton merinos, reported a more or less uniform growth throughout the year, with slightly more growth during those months when green feed was available, and less growth when the ewes were suckling lambs.

Hardy and Tennyson, who studied the influence of wool growth upon wool fineness, gave an illustration of a "tied" lock, showing proportionate monthly growths of wool, but no data were given. From a visual inspection of the "actual size" illustration it would appear that the monthly wool growth was more or less uniform throughout the year.

A recent publication by Hackedorn and Sotola gives the monthly wool growth in Rambouillet ewes and wethers. In these results there was no marked difference in monthly wool growth between wethers whose wool was allowed to grow for four years and in those which were shorn every twelve months.

A wether's fleece of 48 months' growth weighed 62 lb. and attained a length of 10 in. There was no difference in winter and summer wool growth, and the last 12 months' wool growth was just as long as that of any previous twelve months.

EXPERIMENTAL PROCEDURE

Animals Used

Five or six ewes were used in each test, the number depending on mortality and sales. No substitutions were made during the year, but each spring at shearing time young ewes were added so as to have as many ages represented as possible, and to have as near as possible six ewes for each breed in the test.

An inspection of the ear tag numbers of the individual sheep will show the distribution of ages once one is acquainted with the system of numbering. All lambs born in 1921 were numbered from 100 to 199; all those born in 1922 were numbered from 200 to 299; and so on up to 1930, when the lambs were numbered from 0 to 99. In this system an animal with the same number appears once in ten years, but as sheep rarely are kept in the flock for that length of time, this system of numbering is quite simple and practical and is widely used.

The ewes in this experiment were run with the rest of the Rambouillet ewes of the Wyoming Experiment Station flock. This experiment station is located at an elevation of 7,200 ft. and has little pasture land. Consequently the sheep are kept under shelter the greater part of the year, and are fed on alfalfa hay, a grain mixture consisting of barley, oats, and bran, and occasionally some sunflower silage or cabbage.

During the summer months they are turned out during the day on pasture and obtain some green feed, but are returned to the sheep barn in the evening. Some seasons they are fed on green oats as a "soiling crop" during the summer months.

EXPERIMENTAL PROCEDURE

Sampling Methods

The right mid-shoulder area was chosen as the area on which the wool growth studies would be conducted. Three methods of sampling were tried out—

(1) Length of staple on the sheep.
(2) Growth clippings of each month's growth.
(3) Individual staples tied each month and the distance between "ties" measured.

DESCRIPTION OF SAMPLING METHODS

(1) The fleece was parted in the mid-shoulder region and a steel rule inserted with the zero point resting on the surface of the skin. The fleece was then allowed to fall back on the rule, and an average reading of the length of staple in the fleece recorded. Each month this procedure was followed, and the difference between staple lengths represented the growth during the intervening time.

(2) At the beginning of the test a small area of about 2 sq. in. in extent was clipped close to the skin. This area was located in the mid-shoulder region. In order to clip the wool fibres off as close to the skin as possible, a special type of shears were obtained. These were surgeon's shears (8 in. size) with blades angled at 30° on the flat. By pulling the wool fibres up tightly against the blades of the shears, the fibres were cut as close to the skin as would be the case had the area been shaved.

Each month a growth clipping sample was taken from the middle of the area, and the remaining portion of the small area was cleared so that no long fibres could be accidentally included in the following month's growth clipping.

(3) At the beginning of the test a small staple the size of one's little finger was selected and tied with dental floss (similar to surgeon's silk ligature) using a surgeon's knot to counteract any tendency of the knot to slip. The loose ends of the floss were clipped off close to the knot, so that these ends would not catch and pull the "tie" off the staple. Each month a "tie" was made on the same staple, as close to the skin as possible, and at the end of the year's growth each month's growth was plainly marked by the ties.

METHODS OF MEASUREMENT

Staple length on the sheep and the growth as represented by the distance between the "ties" were measured directly by the use of a steel rule graduated in tenths of an inch.

The small sample of monthly growth clippings, when laid out, naturally arranged itself in the form of a thin "sheaf," and as both the proximal and distal ends were cut off at the surface of the skin, the sample would be in the shape of a parallelogram, and a measurement of the average length of the growth clipping was easily taken to the nearest tenth of an inch. In all cases two readings out of three taken were identical, and in over 90% of the cases all three readings were identical.

It was thought advisable to analyse the length of the individual fibres when stretched taut, so as to know whether it would be best to get a frequency table of length of a number of fibres making up a staple or growth clipping "sheaf" or take the average measurement on the entire staple or clipping "sheaf" as one unit.

The old method of clamping each fibre in the jaws of a testing apparatus was thought to be entirely too tedious and slow, and an attempt was made to devise a simpler and faster method.

The following method of measuring individual stretched fibre length has been worked out—

A NEW METHOD OF MEASURING STRETCHED (TAUT) FIBRE LENGTH

A black chenille rug swatch (12 × 18 in. in size), with a deep "pile" (1 in. deep), and a pair of cork or rubber-tipped tweezers, make up the equipment used in this simple method. The deep "pile" of the chenille rug partially holds the individual wool fibres when they are pressed down into it. A steel rule, graduated in tenths of an inch, is laid on the rug in front of the fibre which has been pressed down into the "pile" of the rug. The end of the fibre on the right-hand side is grasped near its end by the cork-tipped tweezers, and the thumb nail of the left hand is placed over the fibre so that the thumb nail is even with the zero point on the rule. Thus when the fibre is drawn taut it pulls along under the thumb nail, but only very gradually as it is gently held by the deep "pile" of the rug in which it is embedded. The tip of the tweezers makes a good pointer, and as the unattached end of the fibre slips out from under the thumb nail, the tension on the fibre as held by the "pile" of the rug is sufficient, so that there is no tendency for the tip of the tweezers to "jump," and an accurate length reading can be made.

The whole "set-up" is shown in illustration Fig. 1. Either 25 or 50 fibres were measured for stretched length, according to the length of the fibres. The growth clippings were much shorter and showed less variation

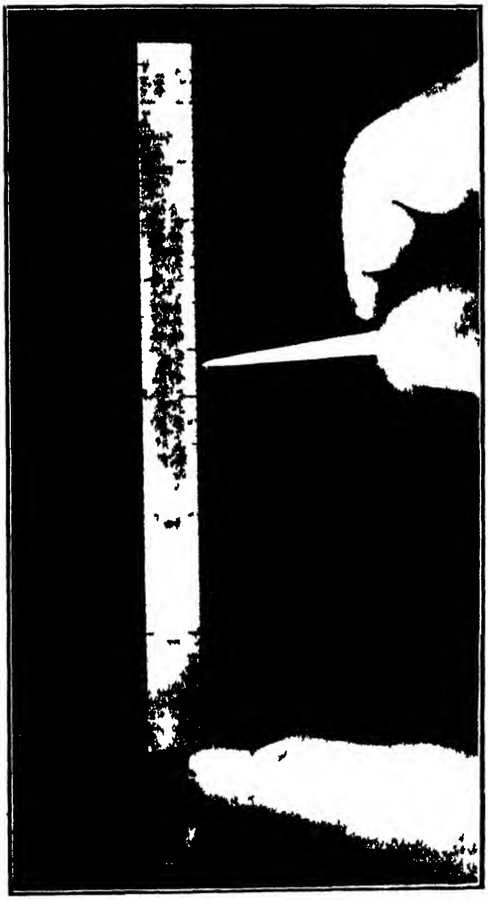


FIG. 1

than the staple samples, and hence 25 fibres were measured from the former and 50 fibres from the latter.

A test was made to find out how many fibres should be measured out of a staple to ensure reasonable accuracy. Six samples were used from the following breeds—F_1 Crossbred (Hampshire × Rambouillet), Rambouillet, Lincoln, Corriedale, Oxford, and Hampshire. All samples were from the 1925 fleeces, which were a full 12 months growth. One hundred fibres were measured for stretched (taut) length from each sample, using the chenille rug method previously described. The measurements were taken to the nearest tenth of an inch, and grouped in units with five fibres in each unit.

Number of Fibres to be Measured to Determine Stretched (Taut) Fibre Length

Length of Stretched (Taut) Fibre in Inches

Number of Fibres Measured	F_1 Crossbred (Hampshire × Rambouillet)		Rambouillet		Lincoln		Corriedale		Oxford		Hampshire		All Si Sample	
	Mean length	Variation from 100	Mean length	Variation from 100	Mean length	Variation from 100	Mean length	Variation from 100	Mean length	Variation from 100	Mean length	Variation from 100	Mean length	Var ti fr 1
5	4·70	·49	3·46	·05	6·54	·11	3·50	·15	6·66	·14	4·04	·23	4·82	·2
10	4·64	·43	3·47	·06	6·57	·14	3·45	·10	6·89	·37	4·11	·30	4·86	·2
15	4·51	·30	3·47	·06	6·65	·22	3·41	·06	6·95	·43	4·08	·27	4·85	·2
20	4·38	·17	3·48	·07	6·69	·26	3·39	·04	6·85	·33	4·06	·25	4·81	·1
25	4·31	·10	3·47	·06	6·74	·31	3·40	·05	6·80	·28	4·05	·24	4·80	·1
30	4·25	·04	3·45	·04	6·83	·40	3·38	·03	6·67	·15	4·00	·19	4·76	·1
35	4·23	·02	3·45	·04	6·75	·32	3·36	·01	6·68	·16	3·98	·17	4·74	·1
40	4·19	·02	3·44	·03	6·74	·31	3·41	·06	6·65	·13	3·96	·15	4·73	·1
45	4·19	·02	3·44	·03	6·75	·32	3·39	·04	6·62	·10	3·91	·10	4·72	·1
50	4·20	·01	3·44	·03	6·71	·28	3·37	·02	6·59	·07	3·93	·12	4·71	·0
55	4·18	·03	3·42	·01	6·68	·25	3·39	·04	6·55	·03	3·89	·08	4·69	·0
60	4·18	·03	3·40	·01	6·63	·20	3·38	·03	6·55	·03	3·89	·08	4·67	·0
65	4·17	·04	3·39	·02	6·53	·10	3·36	·01	6·59	·07	3·87	·06	4·65	·0
70	4·17	·04	3·40	·01	6·54	·11	3·37	·02	6·59	·07	3·86	·05	4·66	·0
75	4·20	·01	3·40	·01	6·55	·12	3·36	·01	6·61	·09	3·86	·05	4·66	·0
80	4·20	·01	3·39	·02	6·50	·07	3·36	·01	6·57	·05	3·86	·05	4·65	·0
85	4·23	·02	3·41	none	6·48	·05	3 35	none	6·55	·03	3·84	·03	4·64	·0
90	4·22	·01	3·41	none	6·43	none	3·35	none	6·53	·01	3·82	·01	4·63	·01
95	4·21	none	3·42	·01	6·45	·02	3·36	·01	6·52	none	3·83	·02	4·63	·01
100	4·21	.—	3·41		6·43		3·35	–	6·52		3·81		4·62	
Error of mean of 100	·032	-	·017		·066	-	·020		·046	—	·035		·040	–
3 Times prob. error		·096		·051		·198	-	060		·138		·105		·120

When comparing the variation of differences from the mean of the entire 100 fibres, it will be noted that in some samples the measurement of 35 fibres was sufficient, while in others as many as 60 fibres should be measured before the difference was less than three times the probable error of the mean length of 100 fibres. The point of accuracy in all the samples seemed to be when around 50 fibres had been measured, so this number was chosen as a standard number of fibres to be measured from each sample.

EXPERIMENTAL PROCEDURE

Comparison of Sampling Methods

"Tied" Staple Method Compared with Growth Clipping Method—It was found impossible, in spite of all precautions, to keep the "ties" on the staples during the first two months after shearing, for all "ties" made in this period were lost. After that period of time was past the "ties" held, with a few

exceptions, and the resulting growth figures agreed closely with those obtained with monthly growth clippings from the same animals.

However, because of the loss of the first two or three "ties" made after shearing, and the strong possibility of later "ties" slipping, the "tie" method was discarded as not comparable to the growth clipping method in accuracy, as one method is positive and the other doubtful in the results obtained.

COMPARISON OF SAMPLING METHODS

Average Staple Length Difference Method, compared with Average Growth Clipping Length Method—In 161 growth determinations with individuals from four different breeds (Rambouillet, Oxford, Hampshire, and Corriedale), the following frequency distribution of monthly wool growth was obtained—

Twelve Months Period of Growth, April 1926 to April 1927
Frequency Distribution

Monthly Growth in tenths of an inch	Staple Length Difference Method					Growth Clipping Length Method Average Length of "Sheaf"				
	Breeds*				All four breeds	Breeds*				All four breeds
	R	O	H	C		R	O	H	C	
Loss	1	0	2	7	10	0	0	0	0	0
0	7	5	5	0	17	0	0	0	0	0
1	10	8	5	2	25	0	0	0	0	0
2	12	7	9	4	32	32	1	12	7	52
3	11	4	2	5	22	15	15	16	11	57
4	7	7	7	2	23	4	10	8	7	29
5	1	4	2	5	12	3	10	3	2	18
6	0	3	3	0	6	0	4	0	0	4
7	3	1	0	0	4	0	0	0	1	1
8	1	1	1	2	5	0	0	0	0	0
9	1	0	1	0	2	0	0	0	0	0
10	0	0	0	1	1	0	0	0	0	0
11	0	0	2	0	2	0	0	0	0	0
Total	54	40	39	28	161	54	40	39	28	161
Mean length ...	·256	·288	·318	·300	·286	·259	·403	·305	·329	·318
†P. E. of mean ...	·019	·022	·031	·034	·128	·008	·011	·010	·014	·060
Coef. of Variability ...	81	73	91	88	84	33	26	30	34	35
‡P. E. of Coef. of Variability ...	8	8	11	13	5	2	2	2	3	1

* **Breeds**— R = Rambouillet O = Oxford; H = Hampshire, C = Corriedale
† P. E. = Probable error.
‡ Coef. of Variability = Coefficient of Variability or per cent. Standard Deviation.

It will be noticed that the staple length method recorded 27 cases or 16·75% of the total with a loss or no growth, a fact which in itself was enough to condemn the method. However, the extreme variability of 84% as compared with 35% is the final convincing argument of the futility of using the staple length difference method.

At no time during the test was there any similarity between measurements by the two methods of sampling, and the violent fluctuations of the figures obtained by the staple length difference method did not show any regularity in their occurrence. The inter-relationship of breeds is interesting. As would be expected, the breeds with longer wool gave the greatest error in the average growth by staple length difference method. However, the

tendency was practically the same in all breeds, and the futility of using staple length differences for ascertaining wool growth is quite apparent.

COMPARISON OF MEASUREMENT METHODS

Stretched (Taut) Fibre Length of Staple compared with Average Length of the Growth Clippings—In this test an area of some four or five square inches in extent was cleared, and a staple of wool taken from this area at the end of each month of growth. It was hoped that by the use of this method of sampling a cumulative "stair-step" perspective of wool growth could be obtained. As the experience with using average staple length differences for growth determination had given extremely unreliable results, the measuring of average staple length was discarded, and a measurement of 50 individaul stretched (taut) fibres was substituted.

The results of 86 growth determinations with three breeds (Corriedale, Hampshire, and Rambouillet) over a period of six months in the 1928-29 growth test gave the following frequency distribution.

Frequency Distribution

Monthly Growth in tenths of an inch	Staple Length Method. Mean stretched fibre length of 50 fibres				Growth Clipping Method. Average Length of "Sheaf"			
	Breeds*			All three breeds	Breeds*			All three breeds
	C	H	R		C	H	R	
Loss	0	0	2	2	0	0	0	0
0	0	0	0	0	0	0	0	0
1	2	0	3	5	0	0	0	0
2	4	4	6	14	12	4	28	44
3	6	2	5	13	12	9	3	24
4	6	5	6	17	6	6	3	15
5	6	3	6	15	1	2	0	3
6	3	5	4	12	0	0	0	0
7	4	1	2	7	0	0	0	0
8	0	1	0	1	0	0	0	0
Total	31	21	34	86	31	21	34	86
Mean length	·413	·448	·359	·400	·287	·329	·226	·273
P. E. of mean ...	·021	·025	·022	·013	·010	·013	·007	·006
Coef. of Variability ...	42	38	54	46	29	26	27	32
P. E of Coef of Variability ...	4	4	6	3	3	3	2	2

*Breeds—C = Corriedale; H = Hampshire; R = Rambouillet.

Again the extreme variation of the length of stretched (taut) fibres in the staple makes itself evident, and although the stretched fibre length gave better results than the staple length difference, still it was not as accurate and uniform as the average length of clipping ("sheaf.") Either by inspection of the distribution data or by comparison of the coefficients of variability. the marked superiority of the average length of the clipping method of measurement is apparent.

Stretched (Taut) Fibre Length of Growth Clippings compared with Average Length of Growth Clippings—Only the growth clipping method has stood out as most reliable in the series of tests thus far reported. It was thought advisable to compare the two methods of measuring the growth clippings.

In 258 growth determinations with four breeds (Corriedale, Hampshire, Rambouillet, and Lincoln), over a period of 14 months from March 1929, to May 1930, the following frequency distribution was obtained—

Frequency Distribution

Monthly Growth in tenths of an inch	Growth Clipping Method. Average Length of "Sheaf"					Growth Clipping Method. Mean Stretched Fibre Length of 25 Fibres				
	Breeds*				All four breeds	Breeds*				All four breeds
	C	H	R	L		C	H	R	L	
	7	7	19	0	33	0	3	16	0	19
3	20	24	43	1	88	13	22	42	0	77
4	24	30	4	2	60	31	31	5	3	70
5	16	4	1	13	34	21	8	1	20	50
6	1	0	0	13	14	3	0	1	11	15
7	0	0	0	13	13	0	1	1	7	9
8	0	0	0	7	7	0	0	1	7	8
9	0	0	0	5	5	0	0	0	7	7
10	0	0	0	2	2	0	0	0	2	2
11	0	0	0	0	0	0	0	0	1	1
12	0	0	0	2	2	0	0	0	0	0
Total	68	65	67	58	258	68	65	67	58	258
Mean growth length ...	·376	·348	·281	·612	·411	·421	·374	·304	·650	·430
P. E. of length	·008	·006	·005	·016	·008	·006	·007	·009	·016	·007
Coefficient of Variability ...	26	22	21	27	44	19	22	35	27	40
P. E. of Coefficient Variability	2	1	1	2	2	1	1	2	1	1

*Breeds—C=Corriedale; H=Hampshire, R=Rambouillet, L=Lincoln

As would be expected, the stretched fibre method gave a slightly larger figure than average length of "sheaf."

COMPARISON OF MEASUREMENT METHODS

The difference between the two systems of measuring growth clippings was so small as to be negligible. In fact the difference ·19 was smaller than three times the probable error of the mean (·21). The coefficients of variability were also quite close together, and here again the difference was practically the same as the probable error. The tendencies were the same in all four breeds under test.

Thus no particular advantage was gained by measuring individual stretched (taut) fibre lengths of a growth clipping "sheaf" rather than taking an average measurement of the "sheaf" as a whole.

In view of the results of all the tests concerning methods of sampling and measurement, the average length of the growth clipping "sheaf" was used throughout the wool growth studies reported in this paper.

As later results will show, the stimulation of the skin by the shears when taking the growth clipping sample, and clearing the area, was not a factor, and physiologists have confirmed this fact in conversations with the writer.

During the first few months after shearing, there was a stimulation of wool growth.

EXPERIMENTAL RESULTS

A frequency distribution of the data given on page 1106 gives the following table—

Monthly Growth in tenths of an inch	Frequency
1	1
2	133
3	95
4	8
5	3
Total	240

Mean — 25
P E of Mean 003

Maximum Variation in Monthly Wool Growth Same Ewe, Same Month, Different Years

READINGS IN TENTHS OF AN INCH

…mpled Ear Tag Number	May	June	July	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	Apr	No Months in Test	Total Variation	No	Av Va…
116	1	1	3	2	1	1	0	1	1	1	0	1	33	13	12	1 0
379	0	0	2	1	0	1	1	0	0	1	1	1	43	8	12	6
447	1	1	2	2	0	1	0	0	1	0	0	1	24	9	12	7
454	0	0	1	1	0	1	2	1	1	1	1	0	31	9	12	7
526	0	1	1	1	1	0	1	1	1	0	0	1	31	8	12	6
703	0	1	1	0	1	1	1	1	1	1	1		23	9	11	9

The average maximum variation of growth in the same ewe during the same month in different years varied from 067 of an inch to 108 of an inch, showing a strong tendency for the same individuals to grow wool uniformly throughout a period of 43 months

WOOL GROWTH BY SEASONS

Two hundred and forty determinations from the Rambouillet growth clipping samples, over the four year period gave the following table of growth by seasons—

Season	Actual Wool Growth in inches	Per cent of Yearly Growth
Spring March April and May	74	25
Summer— June July and August	79	27
Fall—September October and November	74	25
Winter— December January and February	70	23
Total growth for the year	2 97	100

The above table shows a remarkable uniformity of growth throughout the four seasons of the year As would be expected, Fall, Winter, and Spring, those seasons when feed was not so good and when nourishing the unborn and later the suckling lamb, gave less growth than during the summer months when green feed was available Thus do the wool growth determinations co-ordinate as would be expected with the physiological and environmental conditions, favourable circumstances increasing, and those which are unfavourable retarding wool growth

In order to compare these wool growth figures with those reported by a number of investigators in Germany, an arrangement has been made of

Monthly Wool Growth of Rambouillet Ewes 1926-1930. Average Length (Three Readings) of Clipping "Sheaf" in Tenths of an Inch ‡Averages and Variation Figures in Hundredths of an Inch. Right Mid-shoulder Area

Year	1926 to 1927					1927 to 1928					1928 to 1929						1929 to 1930						Total	Num-ber	Avg Mo Grwth	Varia-tion*
Ear Tag Number	116	356	379	446	447	116	379	447	454	526	116	379	454	526	618	703	379	454	526	611	703	847				
Sampled																										
May ...	3	4	2	2	3	2	2	2	2	3	2	2	2	3	3	3	2	2	3	3	3	3	56	22	25	none
June ...	3	3	2	2	3	2	2	2	2	3	2	2	2	2	2	2	2	2	2	3	3	2	50	22	23	—·02
July . .	5	5	4	5	4	3	3	2	3	3	2	2	2	2	2	3	3	3	3	3	3	3	67	22	30	+·05
August	3	2	2	3	4	3	2	2	2	3	1	2	2	2	2	3	3	3	3	4	3	3	57	22	26	+·01
September	2	3	2	3	2	3	2	2	3	3	2	2	3	2	3	2	2	3	3	4	3	2	56	22	25	none
October	2	2	3	2	3	3	2	2	3	3	2	2	2	3	3	2	3	3	3	4	3	3	58	22	26	+·01
November	2	2	2	2	2	2	2	2	2	3	2	2	2	2	2	2	3	4	3	3	3	2	51	22	23	—·02
December	2	2	2	2	2	3	2	2	3	3	2	2	2	2	sold	2	sold	sold	sold	2	3	3	41	18	23	—·02
January ...	2	2	2	2	2	3	2	3	3	3	2	2	2	2	—	2	—			3	3	2	42	18	23	—·02
February .	3	2	3	3	2	2	2	2	3	2	died	2	2	2	—	2		—	—	2	3	3	40	17	24	—·01
March ...	3	2	2	2	2	3	3	2	3	2	—	2	2	2	—	2	—	—	—	3	3	3	41	17	24	—·01
April ...	2	2	2	2	3	3	2	2	3	3	—	—	—	—	—	—	3†	3	2	3	2	3	40	16	25	none
Total Growth .	32	31	28	30	32	32	26	25	32	34	17	22	23	24	17	24	21	23	22	37	35	32	599	—	—	—
No Months Growth ..	12	12	12	12	12	12	12	12	12	12	9	11	11	11	7	11	8	8	8	12	12	12	—	240	—	—
‡Avg M'thly Growth .	27	26	23	25	27	27	22	21	27	28	19	20	21	22	24	22	26	29	28	31	29	27	—	—	25	—

*Variation of mean monthly growth by months from average monthly growth for the entire year
†In 1929 to 1930 all areas were cleared one month sooner than in former years

The maximum growth occurred in the month of July, while the minimum growth was found in June, November, and January
The difference between the maximum and minimum figures was 07

the data showing the wool growth for the first six months, and the following six months after shearing.

As before, there were 240 growth determinations over the period from 1926 to 1930—

	Actual Wool Growth in inches	Per cent. of Yearly Growth
First six months after shearing	1·55	52
Following six months	1·42	48
Total growth for the year	2·97	100

The remarkable uniformity of growth as shown in the four seasons of the year is also apparent when the data are arranged with two growth periods of equal duration from one shearing to the next shearing twelve months later.

THE EFFECT OF SHEARING ON WOOL GROWTH

It has always been a popular idea that wool grows more the first month or two after shearing than during later months. In order to see just how significant the differences would be, the data on five breeds have been arranged so that a comparison could be made of the first and second months independently against the remaining months of the year.

Comparison of First Month's Wool Growth after Shearing with subsequent Growth until the next Shearing

Average Length of Growth Clipping "Sheaf"

Frequency Distribution

Growth in tenths of an inch	First Month's Growth						Subsequent 11 Months' Growth					
	Breeds*					All breeds	Breeds*					All breeds
	L	C	O	H	R		L	C	O	H	R	
1	–	–	–	–	–	–	–	–	–		1	1
2	–	1	–	2	11	14	–	27	3	40	122	192
3	–	9	3	9	10	31	4	66	34	83	85	272
4	–	6	2	5	1	14	25	53	22	59	7	166
5	5	2	0	1	–	8	59	24	17	11	3	114
6	8	0	1	1	–	10	73	1	5	0	–	79
7	7	0	3	2	–	12	36	1	0	1	–	38
8	4	1	0	1	–	6	20	–	0	–	–	20
9	1	–	0	–	–	1	11	–	1	–	–	12
10	–	–	1	–	–	1	2	–	–	–	–	2
11	–	–	–	–	–	0	0	–	–	–	–	0
12	–	–	–	–	–	0	2	–	–	–	–	2
Total ...	25	19	10	21	22	97	232	172	82	194	218	898
Mean in inches ...	·652	·374	·540	·400	·255	·441	·603	·347	·390	·323	·249	·388
P. E. of Mean ...	·015	·019	·048	·024	·008	·136	·007	·005	·009	·004	·003	·004
3 Times error of Mean ...	–	–	–	–	–	·408	–	–	–	–	–	·012

*L=Lincoln; C=Corriedale; O=Oxford; H=Hampshire; R=Rambouillet.

The difference between the average growth the first month and the other eleven months shows a greater growth in the first month. The difference ·053 is over twelve times the probable error, and upholds the general idea that wool grows more the first month after shearing. The same tendency is noted in the different breeds.

A similar arrangement of data comparing the second month's growth with the other eleven months shows the second month's growth to be slightly greater, but the difference this time is only ·018, which is four times the probable error of the mean, a significant figure, but not nearly as conclusive a difference as in the first month's growth.

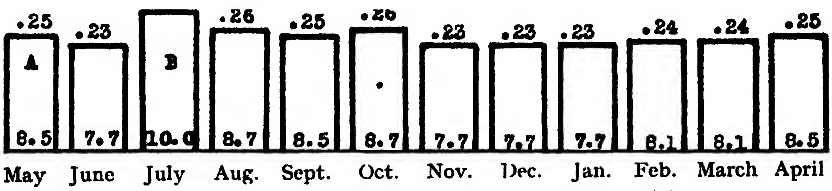
CONCLUSIONS

Rambouillet ewe wool grows more or less uniformly during the year, but is affected slightly during the winter, spring, and summer by the lambing season, and the abundance or lack of green food.

Monthly Wool Growth in Rambouillet Ewes. Growth in hundredths of an inch.
240 Monthly Growth Determinations.
4–6 Ewes, 1926–1930. Sheared on 27th April each year.

Figures on top of columns represent growth in hundredths of an inch.

Figures within columns represent each month's proportionate growth in per cent. of the total growth for the year.



A = First month after shearing. B Green feed available.

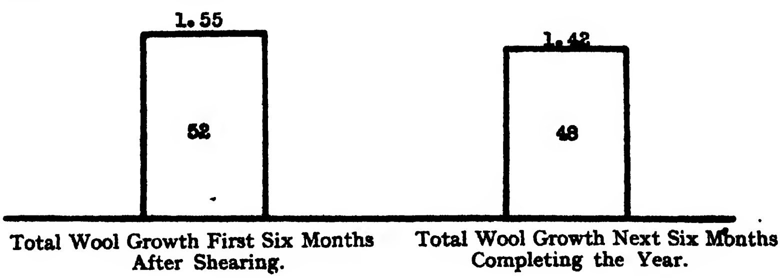
It will be noticed that the monthly wool growth was quite uniform throughout the year, the minimum and maximum monthly growth varying by only ·07 of an inch.

In July only was an abundance of green feed either in the form of green pasture or oat fodder available, and the effect on the wool growth was startling.

If these data are arranged in two periods of six months' growth, they give information which can be compared directly with those reported in the review of literature in this paper.

Comparison of Wool Growth in Rambouillet Ewes by Six-months' Periods, beginning from Shearing Time.

Figures on top of columns are total growth in inches.
Figures within columns are per cent. of yearly growth.



The results in the wool growth test at the Wyoming Experiment Station are in direct opposition to those reported by Rohde, Stohmann, Heyene, Gartner, and Zorn, and in agreement with the results reported by Nordmeyer and Hackedorn and Sotola.

Although there was more growth during the first six months after shearing, it was nowhere so great as the differential of $\frac{2}{3}$ to $\frac{1}{3}$ reported by these investigators. The time of shearing would have no appreciable effect for taking place as it did in the spring (April) it included the large growth in July and October in the first six months of growth, thus raising the proportionate ratio of growth of the first six month's period to the following six month period, making up the year.

Physiologically it would seem logical for wool to grow more or less uniformly if nutrition and health are normal. Fluctuations in growth, due to nutrition and health and reproductive processes, occur according to the severity of these factors. However, the monthly growth inter-relationships seem to keep about the same, even though the yearly growth may be considerably less. Ewe No. 116 gives some interesting information on this point. She was getting old, and during the last year of her life she grew considerably less total length of wool, but the variation from month to month was in the same ratio as in other years, and in the same year for other individuals. This relationship is so evident that it can easily be seen by a mere inspection of the detailed table of data for all ewes in all four years.

SUMMARY

(1) Monthly growth clippings proved out the most accurate and practical method of sampling for wool growth.

(2) The average length of the growth clipping "sheaf" gave results which were so very close to those obtained by measuring 25 individual stretched (taut) fibre lengths that the extra labour in measuring the stretched fibre lengths was unwarranted.

(3) The monthly wool growth of Rambouillet ewes was remarkably uniform throughout the year, and in the four different years.

(4) Wool growth during the first six months after shearing was only slightly greater (52%) than during the following six months (48%).

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7—THE IDENTIFICATION OF FUNGI CAUSING MILDEW IN COTTON GOODS
THE GENUS *ASPERGILLUS*—PART II

By George Smith, M.Sc., A.I.C.

In a previous communication[1] descriptions were given of a number of *Aspergilli* which had been isolated from cotton goods. A number of the species had been proved to be the causal agents in actual cases of mildew damage, whilst the remainder had been found as common spore infections of commercial yarns, and were regarded as possible or probable sources of trouble. Descriptions of a few forms which were still awaiting identification were omitted from that paper. These all belonged to two groups—the *A. glaucus* series, and a group intermediate between *A. glaucus* and *A. fumigatus*, having conidia of the type common in the *A. glaucus* series with all other parts of the fruiting organs more akin to *A. fumigatus*. It is proposed to designate this latter series the *Aspergillus penicilloides* group, since it includes *A. penicilloides* Spegazzini, and since most of the strains bear a strong resemblance to certain *Penicillia* of the Monoverticillate group (formerly *Citromyces*). During the last two years a considerable number of strains belonging to these two groups have been isolated from mildewed cloths and yarns. In addition, by courtesy of the B.C.I.R.A., a number of cultures isolated at the Shirley Institute have been added to the collection, and an analysis of the whole series is now offered.

A recent paper by Galloway[2] gives a list of the species of fungi in the B.C.I.R.A. collection, including representatives of all the great groups of *Aspergilli*, excepting only *A. clavatus*. Galloway includes two groups which he designates respectively the *A. glaucus/fumigatus* and the *A. fumigatus/nidulans* groups, but gives no description of either. Typical members of the two groups have been examined. A representative of the *A. glaucus/fumigatus* group was found to be identical with *A. restrictus* n. sp., described below, whilst the *A. fumigatus/nidulans* group also falls in what is here termed the *A. penicilloides* group, and the one strain it has been possible to examine is probably to be identified as *A. gracilis* Bainier. Galloway, in personal communication, states that his placing was based on the production of reduced sporing heads, and that neither two series of sterigmata nor perithecia, characteristic of *A. nidulans*, have been observed. Since reduced conidial heads are common in several other species besides *A. nidulans*, notably in *A. sydowi* and in *A. candidus*, such occurrence alone can hardly be regarded as a sufficiently typical character to justify the alliance with *A. nidulans*, whereas two series of sterigmata are invariably found in *A. nidulans*, even when the spore head is reduced to a form scarcely recognisable as an *Aspergillus*, and they form the chief mark of distinction between *A. fumigatus* and *A. nidulans*.

THE *ASPERGILLUS GLAUCUS* GROUP

With one possible exception, all the strains which have been studied produce ascopores of small dimensions, that is 6μ or less in long axis. Most of the forms have been identified without difficulty, but a few others appear to differ from all the species of which published descriptions are available. Mangin,[3] from a comparative study of 23 strains belonging to this group, recognised five species and one variety, of which three species produce small

ascospores, namely, *A. repens* de Bary, *A. chevalieri* n. sp., and *A. amstelodami* n. sp. (all cited as *Eurotium* species in the original). Thom and Church[4] in the main endorse Mangin's classification, but recognise three additional species with ascospores less than 6μ in length—*A. ruber* (Spieckermann and Bremer), *A. sejunctus* Bainier and Sartory, and *A. scheelii* B. and S. Unfortunately they somewhat misquote Mangin in two instances. Regarding *A. repens*, they say, "In contrast to Mangin's restriction of the name to forms with ascospores 4·7 by 3·7μ, Sartory includes the whole series with ascospores from 4 to 5·6μ in long axis under the name." Mangin's diagnosis certainly gives the dimensions of the ascospores as 4·7 by 3·7μ, but he actually studied seven forms which he recognised as *A. repens* and, in his table of ascospore characteristics, gives the dimensions respectively as 4·7 by 3·7μ, 4·7 by 3·7 (5·6 by 4·1)μ, 4·7 by 3·7μ, 5·1 by 4·2μ, 4·7 by 3·7μ, 5·1 by 3·6μ, and 4·7 by 3·7 (4·4 by 3·6)μ. He also admits a certain amount of variation in the markings of the spores. The second instance of misquotation is in the description of *A. amstelodami* for which Thom and Church give "Colonies floccose, tardily green, glaucous or olive green, . . . Perithecia numerous, deeply surrounded by floccose mycelium; ascospores with furrow only, hyaline, smooth, 4·7 by 3·7μ," whereas Mangin's own diagnosis gives "Mycelium white, velvety (formant des gazons ras), slightly floccose at margins, becoming covered with conidiophores, small, crowded, greyish-green then glaucous, and finally olive green. Perithecia occurring amongst the conidiophores, small, numerous, sulphur yellow . . . . Ascospores lenticular, hyaline, small, with definite furrow, 4·7 by 3·7μ," and, in his table of ascospore characteristics, he gives "4·7 by 3·7μ, with clear furrow and rounded crests." In view of the diagnostic importance which Thom and Church attach to the presence or absence of crests or ridges bordering the furrow, it is of interest that Mangin's camera lucida drawings of the ascospores of his *A. amstelodami* (see Fig. 2) show crests quite as definite as those figured for two forms of *A. herbariorum*. Regarding the dimensions of the ascospores Mangin gives 4·7 by 3·7μ for both *A. amstelodami* and *A. chevalieri*, but then he examined only a single strain of each of these two species, and it is reasonable to suppose that, if he had studied a series of cultures from different sources, he would have found and recognised, in both species, variations such as he admitted for *A. repens* and *A. herbariorum*. In this connection Thom and Church state that "occasionally a culture is obtained with ascospores regularly and fairly persistently as small as those described for *A. amstelodami*. In many of the closely related strains, however, occasional ascospores of these particular dimensions are found among many somewhat larger . . . ." It seems to be essential to recognise that, throughout the *A. glaucus* series, the dimensions of the ascospores, though more constant than the dimensions of any other parts, may vary appreciably in any one species. Otherwise, in order to cover all the variations encountered, it becomes necessary to postulate a very large number of species and to separate obviously related forms.

For the present study 34 forms, belonging to this group, isolated from mildewed cloths and yarns, and eight forms received from the B.C.I.R.A. (in the following table given Galloway's numbers preceded by "S."), have been examined in comparative culture. They were grown on wort-agar at a temperature of 25° C. Slides were made and dimensions taken of the conidial apparatus as soon as there was abundant production of conidiophores, and of the ascospores as soon as the perithecia were fully matured. The times taken

for the ascospores to ripen varied considerably, from seven to ten days for some forms to six weeks or more for others. All microscopic mounts were made in lacto-phenol. The dimensions and markings of the ascospores are given in the following table—

Table of Ascospore Characteristics

Smooth, without crests, ridges, or furrow

Sp. No.	Dimensions μ
A. 13	4·5–5·0 × 3·5–4·0
C. 6	4·7 × 3·7
C. 11	4·7 × 3·7
C. 12	4·7–5·0 × 3·5–4·0
C. 13	4·7 × 3·7
C. 14	4·7–5·1 × 3·7–4·0
G 3	4·7 × 3·7
G. 7	5·0 × 3·7–4·0
G. 13	4·7–5·0 × 3·7–4·0
G. 16	4·7–5·2 × 3·5–4·0
C. 5	5·0 × 3·7–4·0
S. 1	5·0–5·2 × 3·7–4·0
S. 120	5·1 × 4·0
S. 129	5·0 × 3·8–4·0

With smooth, shallow furrow. No crests

Sp No	Dimensions μ
A 4	6·0 × 4·5
A. 6	6·0 × 3·7–4·6
A. 23	6·0 × 4·5
C. 120	6·0 × 4·2–4·5
C. 130	6·0 × 4·0–4·5
C 140	6·0 × 4·0–4·6
C. 160	6·0 × 4·4
G. 11	6·0 × 4·0–4·5
S 23	6·0 × 4·0–4·2
S. 55	6·0 × 4·2–4·5

With furrow and with small rounded crests

Sp. No.	Dimensions μ
A. 75	5·0–5·5 × 4·2
G. 2	5·0–5·5 × 4·0
G. 5	5·3–6·0 × 4·0–4·2
G. 6	5·0–5·5 × 4·0–4·5
G. 10	5·0–5·5 × 3·5–4·0
G. 12	5·0–5·5 × 4·0–4·2
G. 15	4·7–5·2 × 3·5–4·0
G. 17	5·2–5·6 × 4·0
S. 81	5·0–5·5 × 3·8–4·2
S. 78	5·5–6·2 × 4·5

With deep furrow and well-marked crests

Sp. No.	Dimensions μ
A. 50	4·7 × 3·3
A. 97	4·7–5·0 × 3·2–3·5
G. 1	4·7–5·2 × 3·3–4·0
G. 8	5·0 × 3·3–3·7
G 9	5·0–5·2 × 3·5–3·7
G. 14	5·0–5·2 × 3·5–4·0
S 89	4·7 × 3·3
S. 106	5·0 × 3·5

The table has been divided into four sections, based on the shape of the ascospores. The different groups are, however, equally well characterised by general appearance of colonies.

Group I—The ascospores varied somewhat in dimensions. In a few strains the spores were remarkably uniform in size, whilst in others there was appreciable variation, but in all cases the spores were quite smooth, without a trace of furrow or crests. In general aspect the colonies of all forms showed an intimate mixture of dirty green conidiophores and yellow to brownish-yellow, with margins floccose or stoloniferous and reverse and medium dark brownish-red. They are all, therefore, regarded as *A. repens* (Corda) Saccardo, of which a sufficiently detailed description has already been given.[1]

Group II—The ascospores of all the forms were very similar in shape and dimensions. In all cases the colonies showed an intense red colour on the surface, due to heavy incrustations of pigment on the hyphæ, and a red to

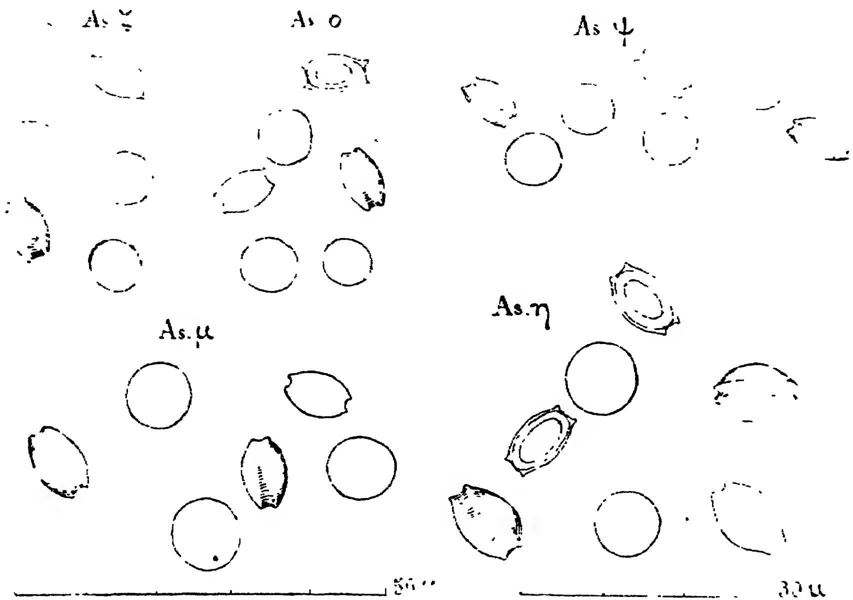

Fig. 8. — Ascospores de diverses formes. As ξ et As o de dimensions 7μ6×... vues de face et de profil. As μ ...

FIG I

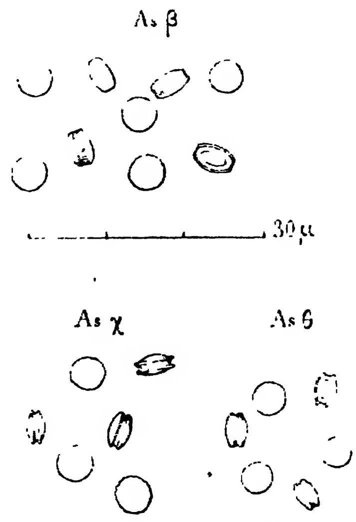

Fig. 7. — Ascospores à petites dimensions 4μ7×3μ7. As β ascospores vues de face et de profil, ces dernières montrent que la gouttière n'est pas apparente. As χ ascospores à gouttière très marquée et à crêtes très apparentes. As 6 ascospores à gouttière nette et à crêtes peu saillantes.

FIG. II

FIG III

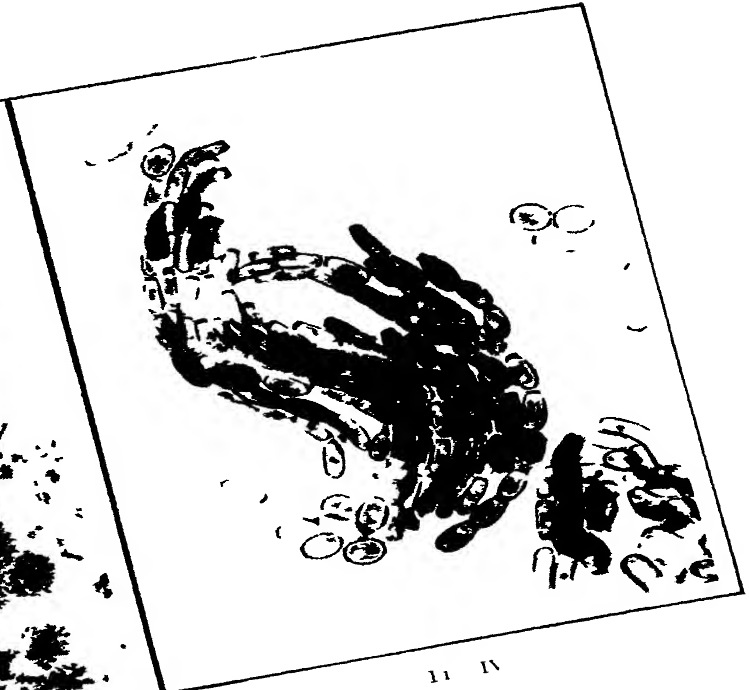

FIG IV

Fig. V

Fig. VI

Fig VII

Fig VIII

almost black colour in reverse. The surface colour was produced rapidly in some strains, tardily in others, but the final appearance was the same. This group belongs clearly with *A. ruber* (Spieckermann and Bremer), which also has been described in the previous paper.

Group III—The general appearance in culture of all the strains in this group, with the exception of S. 78 (see below), was so uniform and characteristic that specific identity is presumed even though the variations in dimensions of the ascospores are somewhat large. They are placed with *A. amstelodami* (Mangin), for which an amended description is here given, sufficiently general to include the whole series of forms, but differing appreciably from Thom and Church's recognition of Mangin's species.

A. amstelodami (Mangin)—Colonies growing well on most common media; on wort-agar at 25° C. growing rapidly, dark bluish or greyish-green thickly speckled with sulphur yellow perithecia, becoming somewhat brown in age; reverse persistently uncoloured; surface velvety with slight floccosity at margins only; stalks arising from substratum, smooth, thin-walled, sometimes septate, brownish, widening upwards, commonly up to 12μ, occasionally more, in diameter; heads hemispherical or sub-globose when young, becoming loosely columnar up to 300μ by 100–150μ; vesicles pear-shaped to nearly globose, fertile over whole surface or over upper two-thirds only, commonly up to 30μ in diameter; sterigmata in one series, mostly 6–9μ by 3·5–4·5μ, varying with temperature of growth and becoming larger and often proliferating to form secondary heads at low temperatures; conidia globose or slightly ovate, rough, 4–6μ in long axis at 20–25° C., becoming slightly larger at lower temperatures; perithecia sulphur yellow, 140μ in diameter; asci 10·5μ in diameter; ascospores with furrow and rounded crests, mostly 5·0–5·5μ by 4·0–4·2μ, occasionally smaller (4·7 × 3·5μ) or larger (6·0 × 4·5μ), with clearness of furrow varying somewhat in different strains but always with definite, though small, crests.

This species is readily distinguished in culture from the remainder of the group under consideration by the striking contrast between the very dark green of the conidiophores and the bright yellow of the perithecia, and by the total lack of colour in the medium.

Form S. 78 was quite distinct from all the other forms studied, in that it produced perithecia only with extreme tardiness. On wort-agar no perithecia have been observed. Sparse ascospore production was induced by growing on media containing a high percentage of cane sugar, such as the sweetened haricot decoction recommended by Mangin. On all media it produced large, dirty-green, conidial heads, with red incrustations on the hyphæ and sometimes a violet colour in the basal felt of mycelium, and with reverse and medium dark dirty-brown. The ascospores, with furrow and small crests, were somewhat larger than those of *A. amstelodami*. The probable place is with *A. herbariorum ser. minor* (Mangin), close to Mangin's "Form ξ," which is described as producing ascospores only under special conditions.

Group IV—Seven of the eight strains, all excepting G. 1, clearly belong with *A. chevalieri* (Mangin). This has not been adequately described in the earlier paper, and is given only a brief description by Thom and Church. The following is an amended diagnosis—

A. chevalieri (Mangin). Colonies on wort-agar at 25° C. predominantly perithecial at first, bright yellow, velvety, gradually showing patches of

dirty bluish-green conidiophores, with more abundant conidial growth at lower temperatures; reverse slowly becoming orange-red to deep red; stalks arising from substratum, smooth, thin-walled, septate, up to 10·5μ in diameter; heads radiate or more or less globose; vesicles flask shaped, fertile all over or on upper half or two-thirds only, up to 25μ or even 35μ in diameter; sterigmata in one series, mostly 7–9μ, occasionally 11μ by 3–5μ: conidia ovate, verrucose, about 5μ long at 25° C., becoming 6–7·5μ at 18–20° C.; perithecia 140μ, occasionally 150μ in diameter; asci 10·5μ in diameter; ascospores with deep furrow and well-marked crests, 4·7–5·2μ by 3·3–3·7μ. Mangin's description of the spores, "shaped like pulleys with bulging sides," is very apt.

Form G. 1 differed from the remainder in producing smooth conidia, nearly globose, 3·5–4μ in diameter. It is doubtful whether this difference alone is sufficient to separate it from the other forms, which it resembles closely in other respects.

THE *ASPERGILLUS PENICILLOIDES* GROUP

Group Characteristics—Colonies growing very poorly and non-characteristically on Czapek agar, growing moderately well or, in a few cases, quite freely on wort-agar, green, dark green, greyish-green, brownish-green, or bluish-grey; surface velvety but frequently heaped and buckled; heads typically columnar; stalks slender, smooth, sinuous, often septate; vesicles inverted cone shaped, fertile only on upper surface; sterigmata in one series, closely packed as in *A. fumigatus;* conidia barrel shaped to ovate, dark coloured, spinulose, resembling the conidia of the *A. glaucus* series rather than those of *A. fumigatus.*

Thom and Church recognise three species belonging to this group—*A. gracilis* Bainier, *A. conicus* Blochwitz, and *A. penicilloides* Spegazzini. *A. conicus*, distinguished by the production of masses of slime enveloping the conidial fructifications, has not been encountered in the present investigation. The available descriptions of the other two species are decidedly fragmentary and, therefore, the diagnoses given below, whilst believed to be based on correct identifications, may possibly differ from the original authors' conceptions.

A. gracilis Bainier. Apparently satisfied by a culture received from the B.C.I.R.A. as representative of Galloway's *A. fumigatus/nidulans* series. Colonies growing only moderately well on wort-agar, pale bluish-green, then dark green, becoming browner and greyer, and partially overgrown with dirty white sterile hyphæ; reverse tardily brown; surface velvety, folded and buckled; heads forming compact slender columns, up to 300μ by 20μ; stalks smooth, sometimes septate, about 3μ in diameter at base, widening upwards to 4–5μ in diameter just below vesicles; vesicles conical, flask shaped or sub-globose, 9–12μ in diameter; sterigmata in one series, closely packed, with outer ones curved towards axis, 5·5–8μ by 1·5–2·5μ; conidia green, barrel shaped, delicately roughened, 4–5μ by 3μ. In general appearance resembling closely certain monoverticillate *Penicillia.*

A. penicilloides Spegazzini (Figs. 3 and 7). The description here given covers a number of strains isolated from mildewed dhooties. Although some of the dimensions are larger than those cited by Thom and Church for a culture accepted by Spegazzini, it is considered that the true affinity of this series of strains is with Spegazzini's species.

Colonies growing fairly slowly on wort-agar, rich dark green with paler edge, turning darker and duller, and finally becoming dirty greenish-grey overgrown with sterile hyphæ; reverse brown, greenish-brown, and dark green in patches; surface much wrinkled and folded; heads globose when young, 40–70μ in diameter, becoming columnar, somewhat ragged, and up to 200μ long; stalks arising either from substratum or from aerial hyphæ, smooth, thin walled, 75–150μ long by 6–10μ in diameter; vesicles rather sharply marked off from stalks, pear shaped to sub-globose, 15–23μ in diameter, fertile over the upper half or two-thirds; sterigmata in one series, crowded, 8–10μ by 2·5–3·5μ; conidia ovate, barrel shaped or nearly spherical, usually showing connective, rough, 3·5–5μ by 3·2–4μ, with very dark coloured walls. Distinguished from the succeeding species by the greener colour of the colonies, by the shape of the heads, particularly when immature, and by the somewhat smaller conidia.

A. restrictus n. sp. (Fig. 5). The following diagnosis covers a large number of strains obtained from mildewed cloths, including one received from the B.C.I.R.A.

Colonies growing very poorly on Czapek agar; growing moderately well on wort-agar, dark dull green, gradually turning grey or brownish-grey; reverse in some cultures uncoloured, in others green to dark green; surface velvety at first, becoming wrinkled and often acquiring a warted appearance; heads forming long, compact, slender columns, up to 350μ by 20–30μ in diameter; stalks arising mostly from substratum but also as branches of aerial hyphæ, commonly 50–100μ, occasionally 150 200μ long by 3–3·5μ in diameter, often with one or two septa, smooth, sinuous, uncoloured; vesicles flask shaped, 7·5–14μ in diameter; sterigmata in one series, borne on upper surface of vesicles only, 6–9μ by 2·5 3μ; conidia rough spinulose, elliptical or somewhat pyriform, often showing a distinct connective, dark greenish-brown, 4–6·5μ by 3–4μ, mostly 4·5–6μ by 3–3·5μ. The young conidia are hyaline and cylindrical and almost appear to be segments of enormously elongated septate sterigmata. They gradually swell without increasing in length, at the same time becoming pigmented, but even in old heads they adhere strongly together in columns of parallel chains and mounts made in lacto-phenol usually show compact, twisted, columnar masses of ripe conidia, both attached to and separated from the heads.

In an extended series of cultures, on a variety of media, no tendency to perithecium formation has been observed.

A. restrictus n. sp. *variety B* (Figs. 4, 6, and 8). One strain, obviously allied to the foregoing, has differed from all others in showing somewhat larger dimensions throughout and, more particularly, in the production of conidia up to 10μ or more in length.

Colonies growing well on wort-agar; columnar heads up to 600μ by 40μ; stalks 3–7μ in diameter; vesicles up to 18μ in diameter; sterigmata mostly 7·5μ by 3–3·5μ, but occasionally attaining 13·5μ by 4·5μ; conidia very dark brownish-green, spinulose, varying much in shape and size, nearly globose 4–7μ in diameter, or ovate to pyriform 5–14μ by 3·6–6·5μ.

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[4] Thom and Church. "The Aspergilli." (London, 1926).

EXPLANATION OF PLATES

Fig. I. Mangin's illustrations of ascospores of *A. herbariorum*.
As. ζ, As. *o*, and As. ψ=*A. herbariorum series minor*.
As. μ, and as. η=*A. herbariorum series major*.

Fig. II. Mangin's drawings of ascospores of three species in the section of the *A. glaucus* group with spores less than 6μ in long axis. As. β=*A. repens*. As. χ=*A. chevalieri*. As. θ=*A. amstelodami*. Note the similarity between As. θ and As. μ.

Fig. III. *A. penicilloides*, photographed from specimen mounted in lacto-phenol. ×250.

Fig. IV. Conidia of *A. restrictus var. B.*, some of them fairly young and definitely cylindrical. ×1,000.

Fig. V. *A. restrictus*, from specimen mounted in lacto-phenol. ×500.

Fig. VI. *A. restrictus var. B.*, mounted. ×250.

Fig. VII. *A. penicilloides*, photographed from living culture in Petri dish, showing heads of various shapes, from nearly globose to definitely columnar. ×50.

Fig. VIII. *A. restrictus var. B.*, from living culture, showing columnar heads up to 600μ long. ×50.

8—THE CHEMICAL ANALYSIS OF RAYONS
I—THE CHEMICAL PROPERTIES OF SOME COMMERCIAL RAYON YARNS

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CONTENTS

INTRODUCTION AND SUMMARY

The present work was undertaken in order to ascertain the composition and amount of the non-cellulosic constituents of commercial rayons, and the extent to which the cellulose itself is chemically modified by the processes involved in the manufacture of the yarns, in the hope that the results would illuminate some effects of the technical operations concerned in the bleaching, dyeing, printing, and finishing of cotton-rayon and all-rayon fabrics.

While within recent years considerable progress has been made in improving the mechanical and physical properties of these yarns, it would appear from a study of the literature that their chemical characteristics have received little attention. Such papers as have been published have recorded the results of very few tests, and their value has often been diminished by the omission of adequate descriptions of the materials used. Possibly this lack of data may be due to a feeling that the rapid improvements in manufacturing technique might render any detailed records of results out of date almost before they were published, but it is considered that the majority of rayon products are now sufficiently stabilised for the accumulation and publication of such data to be worth while. Moreover, an examination of the chemical properties of rayon, showing the kind of variation to be expected in normal commercial samples is a necessary preliminary to the work on the chemical effects of bleaching and finishing now being carried out in the Association's laboratories.

Literature

Kami[15] has determined the percentages of ash and material extractable by solvents in a large number of samples of viscose, several of cuprammonium, and one of acetate rayon, and the water-solubility and sulphur content of a few—chiefly Japanese—varieties, and since his results may not be generally available, they are reproduced in Table V, p. T131. Wahl and Rolland[23] have recorded the copper number (Schwalbe-Braidy), ash, and sulphur content of a few kinds of viscose, cuprammonium, and nitrocellulose rayons (Table VIII, p. T134). These results are substantially confirmed by the present work, but the sulphur values obtained by Wahl and Rolland correspond with those found for undesulphurised rather than desulphurised viscose, and their values for cuprammonium yarns are about ten times as high as the highest now given. The reason for this is not clear. Ristenpart[21] has determined the loss of weight suffered by rayons on treatment with boiling 4% sodium hydroxide solution for 30 minutes—conditions somewhat different from those employed in this investigation—but the order in which his method places the different types is the same as that now found. Ash content has also been studied by Reinthaler,[19] and his range for viscoses (0·2–0·35%) is confirmed, but Courtaulds' Dulenza and the Fibro staple-fibre material now examined do not show the abnormally high values previously reported by him, whilst the lowest content is found for Bemberg cuprammonium yarn made from cotton linters (with acetate rayons next in order) instead of for acetate rayons. His statement that nitrocellulose rayon yarns generally have values exceeding 1% does not hold for the one sample of Obourg material now tested, and the present results show that it is possible to differentiate between cuprammonium rayon yarns made from wood pulp and cotton linters respectively. Several of the materials tested by him were of pre-war manufacture, and, probably, discrepancies between his results and those now recorded are to be attributed to improvements in manufacturing technique that have tended to reduce the non-cellulosic residues to a minimum. Thus, to quote from the figures given by Reinthaler, the 1914 Obourg nitrocellulose rayon yarns had values of 2–2·2%, whilst a 1927 sample had an ash content of only 0·36%—a value in agreement with the 0·43% now found.

Scheme of Work and Results

The materials used in the present investigation have been obtained from comparatively few firms, but the samples themselves may be regarded as fully representative of good quality yarns belonging to the different types of rayon, and in order to obtain as much information as possible about their chemical characteristics and the non-cellulosic impurities they contain, the following properties have been measured for standard (first quality) varieties of viscose, Lilienfeld, cuprammonium, acetate, and nitrocellulose rayons of recent manufacture, mostly of British origin—copper number, loss of weight on boiling with alkali, methylene blue absorption, fluidity in cuprammonium hydroxide solution, ash content and ash alkalinity, material extractable by solvents, sulphur, copper, and iron content, and for acetate rayons, the acetic acid content. Mean values of the experimental results are collected in Table I, and the methods of measurement employed (except for copper and iron) are described, where necessary, in the experimental section.

Inferior grades of rayon are stated to differ from first grade material chiefly in the physical condition of the yarns when sorted in the finished state; in other words, both first and lower grade yarns are spun from the

Ash Alkalinity	Ash Alkalinity per gram of Ash	% Extractable Matter (Ether)	% Sulphur	Mg. of Copper per 100 g.			Mg. of Iron/100g.
				Catalytic	Colorimetric	Gravimetric	
—	—	—	—	—	—	—	—
—	—	—	—	—	-	—	—
—	—	—	—	—	—	—	--
—	—	—	—	—	—	—	—
2·73	13·0	0·57	0·013	0·12	0·12	0·13	1·48
2·08	11·5	0·21	0·005	0·19	0·19	0·17	1·08
1·84	10·8	0·80	0·029	0·14	—	0·32	0·70
1·0	10·0	0·56	0·033	0·11	0·09	0·33	1·63
5·75	14·0	1·36	0·350	0·69	—	1·10	2·2
5·0	21·0	0·31	0·023	—	—	—	-
4·7	23·6	–	—	0·29	—	1·13	0·72
1·9	32·0	0·12	0·010	0·07	—	0·13	2·0
—	—	—	—	0·07	-	—	—
—	—	-	--	—	-		
--	—	—	—	—	-	-	-
4·64	22·1	0·09	0·021	—	—	-	
3·55	25·4	0·15	0·023	0·23	0·17	-	—
5·4	22·6	—	0·046	Trace		0·19	0·85
6·1	14·2		0·074	0·54	-	1·09	3·64
1·8	11·3	0·49	0·02	0·11	0·16	0·15	1·14
3·35	12·0	0·18	0·058	6·1	6·7	8·9	2·34
–		0·24	--		–	–	—
1·15	28·7	2·04	Trace	0·75	0·72	0·54	3·3
—	—	-	—	—	--	—	—
2·0	25·0	2·53	–	-		–	3·3
—		0·24	0·024	8·0	7·4	9·1	4·15
—	—		—	-	-	-	—
4·56	19·3	-		1·00	—	—	—
4·45	18·6	—	—	0·40		0·84	1·2
5·3	21·0		0·006	0·70	-	—	0·9
2·65	16·5	1·97	0·035	6·9	5·9	6·7	3·7
2·33	21·0	--	—	—	—	—	--
—	—	—	.	3·0	3·15	1·65	3·8
2·37	19·2	2·0	0·052	1·6	—	1·75	2·3
—	--	--	—	—		—	—
—	—	-	--	—	-		—
--	-	0·06	0·10	0·18		—	1·2
—	--	--	0·05	—	.	—	—
—	—	-	—	—	—	--	—
—	—	0·01	.	—	—	—	—

e or of purchase by the Institute in the open market.
material dried at 105—110° C.

same solution, but those hanks of the finished yarn that do not comply with the requirements for first quality as regards weight, number of broken filaments, yarn breaks, etc., are classified as lower grade. Whilst this may be true in general, it is possible that the lower grades occasionally include yarns obtained from, say, over-ripe or otherwise inferior spinning solutions, and whereas in the former case the chemical properties of first and lower grade yarns would be the same, in the latter they would differ. Thus the fluidities of the fifteen samples of lower grade viscose rayon, recorded in Table IV, p. T128, mostly lie about the normal figure of 10 for unbleached material, but three values are higher even than the normal figure for bleached viscose. Variations of this kind would be expected when the chemical nature of the spinning solutions was adversely affected. With this exception, no attempt has been made to study the properties of lower grade materials, although such an investigation might be of some value in view of the increasing demand for such yarns for weaving on account of their lower price.

Of the chemical properties mentioned above, the first four are dependent mainly on the extent of chemical modification of the cellulose itself, while the remainder are indicative of the nature and amount of the non-cellulosic impurities, which may be derived from the wood pulp or cotton raw material, free sulphur and sulphur compounds, metallic salts, etc., used during the manufacturing processes, or from the soaps or oils used as yarn dressing agents.

The chemical processes involved in the manufacture of rayons, either from purified cotton or wood pulp, are such that some attack of the cellulose itself is to be expected, since in all such treatments either oxidation or acid attack or both may occur. It is to be anticipated, therefore, that the chemical properties of these materials will resemble those of modified cotton cellulose rather than those of the purified but otherwise unchanged material Table I shows this to be so. Thus, whereas the copper number, loss of weight on boiling with alkali, methylene blue absorption, and fluidity of purified but chemically unchanged cotton are respectively near to zero, 1–1·5%, 0·8–1·0%, and 1–3, the corresponding values for normal viscose are about 1, 6–8%, 1·5–2, and 35–40 (or, in 2% solution, 10–12, see "Fluidity," Experimental Section). For other varieties of rayon the individual values are different; for example, the fluidity range of Lilienfeld and cuprammonium rayon yarns is considerably lower (3–6 in 2% solution) than that of viscose rayon. Enhanced attack of the cellulose, however, is always indicated by increased values of one or more of these properties, and it should therefore be borne in mind in textile processing that rayon yarns behave chemically like over-bleached or acid-attacked cotton. This is illustrated by the loss of weight on boiling with alkali. It has been shown previously[4] that oxycelluloses of copper number about 1, prepared from scoured cotton by the action of different oxidising agents, all lose 6–8% in weight as a result of treatment with boiling 1% sodium hydroxide solution for four hours, and it is now shown that normal viscose rayons, which have about the same copper number, experience the same loss under identical conditions. The amount of this loss is virtually the same as that found when grey, unbleached cottons are scoured under technical conditions, so that a grey cloth woven from cotton and a normal viscose yarn would lose roughly the same percentage of weight from both components in, say, an open or pressure boil, though a viscose rayon of higher copper number would lose more weight in this process. Coupled with the fact that it is difficult to obtain a good white in cotton

without giving the material an efficient pressure boil, this suggests that in dealing with certain classes of mixed cotton-rayon fabrics, such as, for example, handkerchief cloths, in which loss of weight of the rayon would be accompanied by loss of strength, cover, and possibly lustre, it would be well to consider whether greater economy would not be effected in the long run by the use of scoured or bleached, instead of grey cotton warps, when a mild washing treatment, followed if necessary by a very light chemick, would give a good white in both component yarns without detracting from the strength or handle of the fabric.

Apart from its chemical composition, the physical condition of the cellulose, i.e. its degree of swelling or dispersion, plays an important part in determining the behaviour of the rayon material in such operations as dyeing and bleaching. For example, the series plain cotton, mercerised cotton, and viscose rayon represents three stages of increasing degree of dispersion of the cellulose, and if samples of all three are dyed together in the same dyebath, their order of increasing depth of shade is that given. It is, however, unlikely that increasing the degree of dispersion has any effect whatever in giving rise to the higher initial values for rayons of the four properties mentioned above, since the increased dispersion caused by the mercerisation of cotton produces no significant increase in the values of those properties (see Table IX, and Clibbens and Geake,[7,8] and Farrow and Neale[12]). Hence it may be considered that the enhanced degree of modification exhibited by rayons is due to chemical alteration of the cellulose, as distinct from swelling, during the processes concerned in the production of the yarns, and perhaps also of the starting materials themselves.

None of the chemical properties measured can be used to characterise all the varieties examined; thus copper number and loss of weight on boiling with alkali fail to distinguish between viscose, Lilienfeld, and cuprammonium yarns made from wood pulp; methylene blue absorption is lowest for acetate rayons, but is otherwise very variable, and fluidity values are low and approximately the same for Lilienfeld and cuprammonium rayons made from cotton linters (Bemberg type), and are high for acetate varieties, though here they are of little significance because these are not composed wholly of cellulose. The difference between cuprammonium yarns made from wood pulp and from cotton linters is shown by all these properties except methylene blue absorption, and the lower values obtained for the cotton products are presumably connected with the lower initial state of chemical attack of the cellulose in the linters than in the pulp. An illustration of this is afforded by a comparison of the properties of typical samples of these two materials as recorded at the end of Table I, and it is a significant fact that in the manufacture of acetate and nitrocellulose rayons, in which the chemical attack of the cellulose is much greater than obtains with viscose, it is at present impossible to use wood pulp as starting material on an industrial scale.

In general, loss of weight on boiling with alkali runs parallel to copper number, and the order of increasing loss is—cuprammonium, viscose, and Lilienfeld varieties (bleached and unbleached) about 6–11%, nitrocellulose about 19%, and acetate 46–48%. Athough the bulk of the loss of the acetate is due to the removal of acetic acid residues, some of the cellulose material is also lost. It is sometimes stated that acetate rayons are much more resistant to attack by oxidising (bleaching) solutions than are other varieties of rayon; while the truth of this statement is not at present in question, it is

certain that tendering of these materials occurs most readily when they are treated with hot alkaline liquids, owing to loss of acetic acid through the hydrolysis of the cellulose acetate compound. In this case, fluidity measurements yield results the interpretation of which is entirely different from that placed on the results of similar measurements made on cotton and regenerated cellulose rayons. Furthermore, copper number determinations alone are of little value, so that the most obvious method of assessing the extent of tendering of acetate rayons would appear to be by determination of their acetic acid content. The percentages of acetic acid (53–54%) corresponding to the original chemically unchanged materials are given in Table Ia, for different samples of acetate rayon, and values below these are indicative of tendering to a greater or less degree.

Table Ia

Acetic Acid Content of Acetate Rayons

Material	% Acetic Acid	
	Ost Method	Barnett Method
Seraceta (not extracted)	53·4	53·3
,, (extracted)	54·7	—
,, ,,	55·3	54·7
Celanese (not extracted) (190 den.)	54·2	—
,, ,, (150 den.)	53·9	53·7
,, (extracted) (150 den.)	54·7	54·1
Esterified Cotton No 1	27·6	—
,, ,, 2	25·6	—

It is found, however, that the fluidity of partly hydrolysed acetate rayon in cuprammonium hydroxide becomes greater as the degree of hydrolysis increases and that there is a linear relationship between the fluidity and the loss of strength or the loss of acetic acid. This relationship must be attributed to the increase in the proportion of cellulose present in the material as the acetic acid is progressively removed and the use of the fluidity measurement for the assessment of tendering of acetate rayons by saponification is being further elaborated.

All the chemical tests applied agree in showing the chemical inferiority of nitrocellulose rayon compared with other members of the regenerated cellulose type, and its high loss of weight on boiling with alkali is almost sufficient in itself to condemn the use of this yarn as a high grade textile material.

As already indicated, the amount of non-cellulosic residues in rayons is very small, if added dressing agents, such as oil, are neglected; for example, the ash content of the cuprammonium varieties prepared from cotton is less than 0·1%, whilst for the acetate varieties it is about 0·13%, and for normal viscose rayons about 0·2%. Abnormal viscose rayons, i.e., those not desulphurised (Tudenza), or hollow kinds (Celta), and cuprammonium rayon made from wood pulp (Brysilka) have higher values, which, however, are still less than 0·5 per cent. The percentage of matter extracted by organic solvents depends largely, of course, on whether oil or soaps have been used in the manufacture or finishing of the yarns, and on whether the rayon has been desulphurised. It is generally less than 0·5%, but may be as high as

2–2·5% for oiled yarns, while for undesulphurised viscose rayon fairly high values are found owing to the mechanical removal of sulphur during the solvent extraction. The ease with which this substance may be removed mechanically is shown by the fact that when such yarn is used as weft in the loom, a fine yellow deposit of sulphur is often found round the eye of the shuttle.

Owing to the presence of sulphur in the free state, or in unstable compounds, the total amount of this element present is not necessarily included in the values for ash content, and an estimate of the total impurities can only be made by taking into consideration ash and sulphur contents and extractable matter. An average value of the sulphur content is about 0·02%, but higher values, not exceeding about 0·06%, are found for the acetate and Nuera Lilienfeld varieties, and that for undesulphurised viscose rayon (Tudenza) is about ten times as high as for the desulphurised product. Bemberg cuprammonium rayon, made from cotton linters, contains only a trace of sulphur, whereas the Brysilka, from wood pulp, may have the average amount of 0·02%; hence the differentiation between viscose and cuprammonium rayons by means of a sulphur determination is trustworthy only in so far as it is certain that the cuprammonium material under examination was made from cotton. It has frequently been laid down in the technical literature that viscose and cuprammonium rayons may be distinguished from one another by the presence of sulphur and absence of copper in the former, and the reverse in the latter, but it is now shown that both elements are generally to be found in both types of material. Whilst such statements may have had some foundation in the earlier days of manufacture, when the amounts of impurity left in the yarns were much larger than they are to-day, and when less rigorous methods of analysis were employed, the present investigation shows that modern practice has tended towards the elimination of all but the smallest amounts of non-cellulosic residues, and that, therefore, all such qualitative tests as the above must be reconsidered in the light of this knowledge.

The results of further examination show that the Tenasco Lilienfeld rayon contains combined sulphuric acid. This has not been found in any of the other regenerated cellulose yarns examined, although acetate rayons[5] are known to contain such acid.

Additional information regarding the composition of the ash is given by the ash alkalinity, copper, and iron values. Abnormally high ash alkalinities are shown in Table I for Obourg, Tudenza, and Celta viscoses, the staple-fibre products Fibro and Vistra, and for the Brysilka cuprammonium rayons, but while these are normally accompanied by high alkalinity per gram of ash, the reverse holds for Vistra and Tudenza, which therefore contain a large percentage of inorganic matter incapable of neutralising acid, e.g. silica, stable neutral salts, and so forth.

Considerable importance has been attached to the determination of the heavy metal content of rayons, since the yarns themselves are very susceptible to attack by chemical agents in virtue of the high degree of dispersion of the cellulose of which they are composed, and traces of such metals are well known to exert catalytic action in accelerating the attack of cellulose by hypochlorite and other oxidising liquids, such as are used in the bleaching of textile fabrics. It is not impossible, therefore, that rayons with a high heavy metal content might be more easily tendered than those of lower content on

this account, and that certain observed cases of local tendering in rayon yarns and fabrics might be attributable to this cause.

Qualitative analysis of the ash obtained both by the ordinary and by acid ashing methods showed the presence of copper, iron, aluminium, calcium, sodium, and in some yarns traces of zinc, whilst lead, chromium, nickel, and manganese were absent, and since the only metals present of catalytic importance are copper and iron, quantitative determinations were confined to these. The largest amounts of copper found were of the order 8–10 mgm. per 100 g. of dry rayon, and this quantity is so small that unless almost the whole were localised at one place in the yarn—an extremely unlikely state of affairs—the possibility of damage in bleaching due to catalytic effects such as those suggested may be considered small. It was surprising to find that the highest copper contents were shown not by the cuprammonium yarns, but by the acetate and Tenasco (Lilienfeld) rayons, which gave values of 1·6–9 mgm. per 100 gm. Cuprammonium varieties—with the exception of the 1928 quality Brysilka, which was a standard product at the time of its purchase, but has now been replaced by a superior yarn—have a mean value of about 0·6 mgm. whilst that for normal desulphurised viscose rayons is about 0·22 mgm.

The copper values given in Table I were obtained by analysis of a hydrochloric acid solution of the ash remaining after complete combustion of the rayon in a platinum dish; the factors affecting loss of platinum from the dish and the quantitative recovery of copper under the conditions of ashing and of dissolution of the residue employed will be discussed in a separate paper. It will be shown that the loss of copper probably does not exceed 10% of the amount found, and may be much less than this. Such an error does not significantly affect the conclusions drawn from the values given.

Iron content does not necessarily run parallel to copper content, although viscose rayons have the lowest values of both. For these yarns the range is 0·7–2 mgm. and for all other varieties about 2·3–4·2 mgm. per 100 gm. of dry rayon. Reference to Table I shows that for many of the viscose samples the total iron and copper content represents only about 1%, and for acetate rayons 6–7% of the ash; hence the heavy metal content of good quality yarns of any variety may for all ordinary purposes be considered negligible.

DISCUSSION OF RESULTS

I—The Extent of Chemical Modification of the Cellulose

It has already been stated that in all varieties of rayon the cellulose has suffered chemical attack, but the extent of this modification varies according to the type of yarn, the starting material used in its manufacture, and the conditions of any bleaching treatment to which the material has been submitted. Further, an estimation of the degree of chemical attack is dependent to some extent on the particular test or tests used as a means of measurement. For example, a high copper number may result from tendering of the cellulose, or it may be due to non-cellulosic impurities associated with substantially undamaged cellulose in the yarn. Similarly, the loss of weight on boiling with alkali, the methylene blue absorption, and the fluidity may also be affected by the presence of impurities. Previous work[3] on the chemical attack of cotton cellulose has also shown that under some conditions of bleaching a high copper number and a low methylene blue absorption may be obtained for the same material, while under others exactly the

reverse is found; hence the danger of relying solely upon one chemical test as a measure of the modification of cellulose cannot be too strongly emphasised. When chemical damage of the material has been considerable, as, for example, in the Obourg nitrocellulose rayon (see Table I), enhanced values for all these properties are obtained, but for comparatively mild attack some may be high while others are low, as for the Obourg viscose rayon, where relatively high copper number and methylene blue absorption are accompanied by low loss of weight and fluidity. The effect of non-cellulosic impurities in significantly modifying such values must, however, be considered very small, except for the methylene blue absorption, in which case ash alkalinity is known to be of some importance. As with cotton, there can be no doubt that the fluidity measurement affords the most reliable means of estimating the extent of chemical attack.

Copper Number

The values for viscose rayon, including staple-fibre materials, lie within the range 0·8–1·2, except for Obourg and Celta (hollow) varieties, where they are abnormally high. A high value is also recorded for one of the bleached Moresia yarns, but there it is accompanied by a high fluidity and may no doubt be ascribed to the yarn bleaching treatment. Lilienfeld rayons in the unbleached state behave like ordinary viscoses, whilst the cuprammonium yarns show two ranges of values—1–1·5 and 0·5–0·6; the former covers the normal viscose range, while the latter is considerably below it, and it is significant that viscose rayons and the cuprammonium rayon of the type with higher copper number (Brysilka) are manufactured from wood pulp, whereas those corresponding with the lower range are made from cotton linters; the former material is, of course, more degraded chemically than the latter (see Table I, wood pulp and cotton linters).

Both the acetate and nitrocellulose rayons have high copper numbers ranging from about 2·8–3·2, but whilst there can be no doubt that this is due to chemical degradation of the cellulose units in the latter, it does not necessarily follow that the copper number of a cellulose ester can be interpreted in exactly the same way as that of an all-cellulose substance, such as viscose- or cotton-cellulose. The following results, however, indicate that the high value obtained for acetate rayon must still be ascribed to chemical attack of the cellulose units themselves in the same way as for ordinary cellulose. Thus, the cellulosic residue remaining after the complete hydrolysis of acetate rayon (Seraceta yarn) with dilute sodium hydroxide solution—conditions that have a negligible effect in increasing the extent of chemical modification of the cellulose—has a fluidity of 12–13 in 2% solution and a copper number of 2·5, both of which are high even for a regenerated cellulose. On the other hand, the copper number of a mixture of viscose rayon and sodium acetate in the proportions that would be present if, e.g. Seraceta yarn were completely hydrolysed with alkali (as must happen during the boiling treatment with the alkaline solutions used in the determination of copper number) to give sodium acetate and a residue similar to viscose cellulose, is 0·84, i.e. no higher than that of normal viscose rayon itself.

As is well known, the copper number of a modified cellulose is diminished by treatment of the material with alkaline solutions, more especially if they are hot, owing to dissolution of some of the reducing substances in the liquid. Increasing hydrolysis of acetate rayon with an alkaline solution also causes a progressive fall of copper number, and it must be remembered

when assessing the value of this property that a high copper number may correspond with no tendering, whereas a lower value may coincide with considerable loss of strength owing to hydrolysis.

Loss of Weight on Boiling with Alkali

It has been shown previously[3,11] that for the initial stages of chemical attack of cotton cellulose the loss of weight on boiling with alkali under the conditions standardised is approximately proportional to the copper number of the modified material, and it would be anticipated, therefore, that the losses suffered by rayon yarns would be greater the higher their copper numbers. Reference to Table I shows that, in general, this is so. Thus for viscose, cuprammonium, and Lilienfeld rayons of copper number up to about 1·2 the loss is about 6–8%, for those of higher copper number up to 1·5 it is about 11%, whilst nitrocellulose rayon of copper number 2·75 loses 19%; these are the losses that would be expected according to the relation established by Clibbens, Geake, and Ridge[11], on the assumption that rayons of the regenerated cellulose type behave chemically like oxycelluloses of the same copper number prepared by the oxidation of cotton. Naturally the highest loss is found for acetate rayons, since under these conditions of treatment complete hydrolysis of the cellulose acetate occurs. For Courtaulds' Seraceta yarn, which contains about 2% of material extractable by solvents, complete hydrolysis corresponds with the loss of weight, due to the removal of acetic acid residues, of 38%, and since the dressing material is also removed by the boiling, a total loss of 40% would be expected. Under the standard conditions, however, a loss of about 48% is found, from which it must be concluded that roughly 8% of cellulosic material is simultaneously removed.

The effect of prolonging the time of boiling with alkali beyond 1 hour is small, since, for example, Tudenza yarn, which showed a loss of 6·8% after one hour, lost only 7·3% as a result of four hours treatment, so that the bulk of the soluble matter is removed during the early stages of the boil.

Methylene Blue Absorption

The methylene blue absorption of viscose rayons ranges from about 1·3–2, and, as with their copper numbers, the values of the Obourg and Celta varieties are high; the highest values, however, are found for the staple-fibre products Vistra and Fibro, although their corresponding copper numbers are low. With the exception of the 1928 Brysilka—which was known to be of inferior quality from its chemical properties—cuprammonium varieties have values within the viscose range, while the acetate rayons have the lowest absorptions measured, 0·8–1·2. In this respect their behaviour towards the dyestuff is similar to that towards water; for example, the moisture content of these yarns is generally less than 6%, whereas that of viscose rayons, and other types of regenerated cellulose, is near to 11% under the ordinary conditions of temperature and humidity. High values of over 2 are obtained for the Lilienfeld yarns, and these might be expected if the materials retain combined sulphuric acid owing to the conditions of their preparation. Thus, it has been shown by Clibbens and Geake[6] that whilst attack of cotton cellulose at the ordinary temperature by hydrochloric or sulphuric acids of relatively low concentration is accompanied by a decrease of methylene blue absorption, when sulphuric acid is used in concentrations of 50% or over, an increased absorption results which is definitely

associated with an enhanced retention of acid. Lilienfeld yarns are manufactured by spinning the viscose solution into coagulating baths of 50–85% sulphuric acid, with or without the addition of salts, and in these circumstances retention of acid is not improbable. In the experiments made by Clibbens and Geake,[8] combined sulphuric acid was found as a result of steeping the cotton in the relatively concentrated solutions for some hours, whereas in the manufacture of the Lilienfeld rayons the time of contact with the acid must be comparatively short, but it should be remembered that prior to and during coagulation the cellulose present in the viscose is in a state of maximum liability to chemical attack, and therefore an effect that takes some hours to produce with normal cotton may occur in a few minutes with freshly precipitated cellulose. It is very unlikely that the high absorptions shown for the staple-fibre products Fibro and Vistra are due to retention of acid, because these materials are made under substantially the same conditions as the ordinary viscose rayons, i.e. the viscose solutions are coagulated by means of dilute acid, and/or salt baths, and it is more probable that here they are to be attributed to the abnormally high ash contents and ash alkalinities of these materials. In order to examine further the reasons suggested for the high absorptions of the Lilienfeld and staple-fibre products, the following experiments were undertaken. It has been shown previously[3] that cotton materials that have a high ash content and ash alkalinity also have a high methylene blue absorption, but if the amount of alkaline ash constituent is reduced by acid washing a corresponding fall of absorption occurs. On the other hand,[10] if the high absorption is due to combined sulphuric acid, even a prolonged boil with alkali fails to remove more than about 50% of this acid, and the absorption cannot be reduced to a normal low value. Samples of the Vistra and Fibro staple fibre, and of the Durafil and Tenasco Lilienfeld rayons, were accordingly steeped in dilute (0·1*N*) hydrochloric acid for half an hour, washed to neutrality with distilled water, dried in the air, and their absorptions again found. The results are given in Table II, and it is seen that whereas the values for the Vistra, Fibro, and Durafil are considerably reduced by this treatment, that of the Tenasco is unchanged. Hence, soluble material to which their high absorptions are partly due, has been removed from the former but not from the latter. These values also show that there is a difference between the Durafil and Tenasco Lilienfeld yarns in that the high absorption of the former is due to the presence of soluble impurities, but that of the latter is not, as will be seen later, and a further difference between these materials is shown by their respective values for ash, ash alkalinity, and sulphur content (Table I). It has also been shown[8] that a comparison of the methylene blue absorptions obtained by steeping the material in dye solutions of pH 7 and pH 2·7 gives definite information whether the chemical attack of cotton, which gives rise to a high absorption in neutral solution, has been caused by oxidising action (over bleaching) or by acid attack under such conditions that combined acid is retained by the cellulose. Thus, oxycelluloses show a pronounced decrease of absorption from the acid dye solution compared with the neutral liquid, but hydrocelluloses show only a small decrease or even increased values in the pH 2·7 solution. Measurements of the absorptions of the above materials, and also of Courtaulds' "A Quality" Viscose, were accordingly made in these dye solutions on separate samples of the well cut-up and mixed material; the results are given in Table III. (It was not found practicable to measure

the absorptions on the same sample in the two liquids in the manner recommended by Clibbens and Geake, because, even after four treatments with boiling acetic acid, a considerable amount of methylene blue was left on the fibres after the first absorption measurement, and this interfered with the second determination.) The values recorded show that with all the materials except Tenasco a considerable fall of absorption occurs for the *p*H 2·7 solution,

Table II

Methylene Blue Absorptions of Lilienfeld and Staple Fibre Rayons

Variety	Absorption Millimoles per 100 gm. of Dry Material	
	Before	After Acid Washing
Lilienfeld—		
Courtaulds' Durafil	2·14, 2·20, 2·07, 2·12	1·50
Nuera Tenasco	2·07, 1·67, 2·23, 2·18	2·23
Staple Fibre—		
Vistra	2·36	1·72
Fibro	4·56 (1 gm. Sample)*	2·3

*When 2·5 g. of this material was used the dye solution was almost completely exhausted, so that the smaller weight was taken.

Table III

Methylene Blue Absorptions from Solutions of *p*H 7 and *p*H 2·7

Material (Acid Washed)	Absorption Millimoles per 100 gm. of Dry Material	
	*p*H 7	*p*H 2·7
Lilienfeld—Durafil	1·50	0·92
Tenasco	1·79	1·75
Staple Fibre—Vistra	1·72	1·3
Fibro	2·3	1·18
Viscose—"A" Quality	1·75	0·94

Table IIIa

Sulphur Content of Lilienfeld and Viscose Staple Fibre Rayons after Washing with Acid

Material	% Sulphur	
	Before Acid Wash	After
Lilienfeld—Tenasco	0·058	0·058
Durafil	0·02	0·012
Staple Fibre—Vistra	0·074	0·020
Fibro	0·046	0·026

whilst with Tenasco no significant change is produced; the presence of combined acid is therefore indicated for this, but not for the other materials. Further support is given by the fact that the Tenasco yarn is the only one the sulphur content of which is not reduced by washing with acid and water, as shown by the figures recorded in Table IIIa. No reduction would be expected if the sulphur were present as combined acid, but otherwise (except perhaps if it were present as elementary sulphur) a considerable fall

should result. The presence of free sulphur, however, is of no importance in this connection, because this substance has no effect in raising the methylene blue absorption; for example, the absorption value for Tudenza viscose rayon (Table I) is no higher than that of the Harbens sample, although its sulphur content—largely free sulphur—is 35 times greater.

Reference to Table II shows that the absorption values of the Tenasco yarn are both high and variable, whilst those of Courtaulds' Durafil are also high but perhaps less variable. For cotton fabrics it has been found previously that a high and variable absorption coincides with unlevel dyeing properties, and it may be that the reported difficulty of obtaining level dyeing on some Lilienfeld yarns is also associated with high and variable methylene blue absorptions.

Table IV

Fluidities of Commercial Rayons

Sample	Origin	Fluidity
Viscoses—		
Celta	From yarn manufacturer ...	14·1, 12·4.
Tudenza	,, ,, ..	8·0.
"A" Quality	,, ,, ...	9·8, 9·7.
Dulesco	,, ,, ..	11·1, 10·5, 10·5, 10·2, 11·0.
Escorto	,, ,, ..	9·0.
,, ...	From winder (pirns) ..	10·0, 10·2, 10·7, 10·0.
Dulenza	From yarn manufacturer ..	11·1.
Harbens' Grade I .	,, ,, ..	9·7.
,, Lower Grade ..	.. ..	9·5, 10·4.
,, ,, ..	Weft from 15 samples of grey cotton-rayon cloth	15·4, 10·3, 10·6, 11·3, 14·5, 14·7, 12·2, 11·4, 11·4, 10·2, 9·8, 10·4, 10·2, 10·7, 10·5.
Moresia (Scottish) 150 den (bleached)	From yarn manufacturer..	11·5.
,, ,, 300 den	,, ,, ..	14·2.
Obourg	From yarn manufacturer ..	6·7.
Snia	,, ,, ...	9·9.
Lilienfelds—		
Durafil	From yarn manufacturer ..	4·26, 4·29, 4·01, 3·58, 3·54.
,, ...	Pirns from winder	3·78, 3·80.
Tenasco (unbleached) .	From yarn manufacturer .	2·90.
,, (bleached) ..	,, ,, .	6·3.
Cuprammonium –		
Bemberg	From yarn manufacturer ..	2·86.
I.G. Bemberg	,, ,, ..	3·15.
Bemberg	From yarn winder (pirns) .	2·64, 2·65, 2·69.
Brysilka	From yarn manufacturer .	6·1, 5·8, 5·4, 5·2.
,, (bleached) ..	,, ,, .	7·4.
,, ...	,, ,, ..	6·9.
,, ...	Pirns from yarn winder .	6·6, 6·7, 6·4.
,, ("W" Quality) .	From yarn manufacturer ..	4·1.
,, ("C" Quality) .	,, ,, ..	5·84.
Staple Fibre—		
Fibro (Courtaulds') ..	From yarn manufacturer ..	9·71, 9·64.
Vistra	,, ,, ...	4·23, 4·15.

Fluidity

Mean fluidity results are given in Table I, and individual measurements are recorded separately in Table IV, which indicates to some extent the variability met with in technical yarns and in different samples from the same delivery.

The range for normal viscose rayons is about 9–11·5, although in some cases this is exceeded. For example, Celta, some of the Harbens varieties, Moresia, etc., have high values, which may be due either to the bleaching treatment given by the yarn manufacturer or to variations from the normal conditions of preparation of the viscose solution—over-ripening of the alkali cellulose, etc. The remaining varieties have, generally, lower ranges, 3–4 for Lilienfelds, 2·5–3·5 for cuprammonium rayon made from cotton linters, and about 4–6 for that made from wood pulp, but the Obourg nitrocellulose sample has the high value of 16·7, which accords with the high values for the other properties of this material.

Of the staple-fibre products, Courtaulds' Fibro has a fluidity corresponding with that of a normal, good quality viscose rayon, whilst Vistra (I.G. Farbenindustrie A.-G.) compares with Lilienfeld or cuprammonium yarns. According to Reinthaler,[19] Vistra is spun from unripened viscose, and the alkali cellulose used in its preparation is also allowed to ripen only a little; these factors, which both make for decreased chemical modification of the cellulose units, are sufficient to account for this low value. The differences between the values for viscose rayons and those of the Lilienfeld and cuprammonium varieties must be ascribed to differences in the properties of the starting materials, to differences in the extent of chemical attack of the cellulose in the manufacturing processes, or to both.

From the values of the chemical properties of samples of wood pulp and cotton linters, recorded at the end of Table I, it is evident that, if the same process were used for both, rayon prepared from the former would be chemically inferior to that from the latter. Also, yarn manufactured from wood pulp which has a higher α-cellulose content (i.e. from material which is superior from the point of view of its chemical properties) is known to be chemically superior to that made by the same process from pulp with a lower α-cellulose content.

The effect of bleaching in raising the fluidity value is shown by a few of the examples in Tables I and IV, but results of a detailed investigation of the effects of acid and oxidising attack on this property of rayons will be communicated later.

The Acetic Acid Content of Acetate Rayons

The amount of acetic acid obtained by the complete hydrolysis of acetate rayons that have not been submitted to ether extraction in order to remove surface oil or soap is about 53–54%, calculated on the dry weight of the original acetate yarn. Since the glucose residues from which cellulose is built up each contain three hydroxyl groups capable of acetylation, the percentages of acetic acid that would be obtained from the theoretical mono-, di-, and tri-acetates are respectively 29·4, 48·7, and 62·5%, from which it follows that the purified (i.e. solvent-extracted) acetate rayon yarns contain approximately 2·4 acetyl groups per $C_6H_{10}O_5$ unit.

A few values for the acetic acid content of some commercial esterified cottons are also given in Table Ia, and here the amount of acetic acid in combination with the cellulose is less than corresponds with one acetyl group per $C_6H_{10}O_5$ unit.

The determination of the acetic acid content of acetate rayons by the Ost[18] method is to some extent unsatisfactory, because the procedure involves steam distillation of the hydrolysed product, and the titration of a large volume (roughly 2 litres) of distillate which contains a relatively

small amount of acetic acid. Further, in an experiment in which distillation was continued for six hours, traces of acid were still being carried over in the condensate. Although the error involved in judging the exact end-point is of minor importance in determining the approximate acetic acid content of an unhydrolysed acetate rayon, it is of considerable moment when a comparison is being made between the relative degrees of hydrolysis of two partially hydrolysed materials which have been treated in very nearly the same manner, because here the difference found may depend on very small titration differences, and a variation of a fraction of a cubic-centimetre in estimating the end-point of each distillation may then make a considerable difference in the degrees of hydrolysis found.

Barnett's method,[2] on the other hand, does not depend on steam distillation (see p. T138), and gives good results for yarns that are completely soluble in acetone, but since partially hydrolysed material is incompletely soluble, this method cannot be used for determination of the degree of hydrolysis.

An investigation of other methods for the accurate determination of relatively small differences of acetic acid content is being made in order to overcome these difficulties.

II—The Non-cellulosic Impurities

Ash Content and Ash Alkalinity

The comprehensive table of ash contents given by Kami (Table V) shows that the values for all types of rayon vary from 0·05 to 2·07%, with an average of about 0·25 per cent. Kami states that higher values are given by dyed material, and that the actual magnitude of the ash content varies according to the country of origin of the rayon; for German yarns it is about 0·15%, and for French about 0·40%, and he ascribes this variation to differences in the cellulose used and in the methods of coagulation, washing, and after-treatment.

Reference to Table I shows that values of the same order are obtained by the present workers. The mean for all the samples examined is 0·21, but since only a few foreign rayons have been used it is not possible to differentiate varieties according to country of origin. In general, it may be said that the ash content of modern rayons is so low as to make its determination of little value. The Bemberg yarns (cuprammonium, prepared from cotton linters) have the lowest content, less than 0·1%, acetate yarns are next in order, 0·09–0·16%, and the remainder have values up to about 0·35%. Abnormally high figures, about 0·4%, are given for the undesulphurised Tudenza, Vistra staple-fibre, and the Obourg nitrocellulose rayon. These values vary in much the same way as those for bleached cottons, which are entirely dependent on the conditions of bleaching and washing of the material. Thus, well-scoured fabric or yarn washed with acid in the laboratory has a negligible ash content of 0·05% or less—comparable with that of the German Bemberg yarns—whereas technically bleached and washed material may have values of over 0·3% according to the extent of scouring, the efficiency of the acid wash, and the alkalinity of the final wash water. No values for rayons approaching those for raw cottons (1·2–1·3%),[13] or the high values for Givet and Lyonnaise viscose rayon given by Kami (Table V), have been found by the present authors.

As previously found for bleached cottons, ash alkalinity runs parallel to ash content, but if these quantities are plotted against one another it is found

Table V
Properties of Rayons
(Y. Kami, *J. Cellulose Inst.*, Tokyo, 1929, **5**, 234–236).

Type of Rayon	Ash %	Fat %	Water Solubility %	Sulphur Content %
Japanese I Viscose	0·12	0·42	1·80	0·02
Japanese II ,, ...	0·18	0·50	2·22	0·03
Japanese III ,, ...	0·24	0·58	2·36	0·03
Japanese IV ,, ...	0·15	0·23	1·21	0·03
Courtaulds' Viscose	0·24	0·59	1·89	—
Western Viscose	0·16	0·67		
Glanzstoff Viscose	0·28	0·47		
,, ,, ...	0·57	0·28		
Borvisk Viscose	0·21	0·62		
Glanzfaden Viscose	0·15	0·33		
Viscosa Viscose	0·15	0·84		
Spinfaser Viscose	0·05	0·36		
Spinnstoff-Glauchau	0·10	0·17		
Spinnstoff-Zehlendorf	0·08	0·76		
Fr. Kuttner	0·11	0·31		
Glanzstoff	0·20	0·20		
,, ...	0·33	0·51		
Enka Viscose	0·25	0·70		
Breda Viscose	0·25	0·18		
Chatillon Viscose	0·27	0·61		
,, ,, ...	0·20	0·61		
Snia Viscose	0·33	0·30		
,, ...	0·39	0·29		
Vareda Viscose	0·59	0·12		
La Soie Artificielle Borvisk Viscose	0·59	0·72		
,, ,, ,,	0·48	0·77		
Italiana della Viscosa	0·25	0·15		
National de la Viscose	0·21	0·57		
Besançon Viscose	0·35	0·62		
,, ,, ...	0·80	0·49		
Givet Viscose	0·32	0·59		
,, ...	1·84	0·65		
Izieux Viscose	0·33	0·84		
Française de la Viscose ...	0·40	0·44		
St. Etienne Viscose	0·31	0·18		
Lyonnaise Viscose	0·37	0·88		
,, ,, ...	2·07	0·25		
Mulhouse Viscose	0·57	0·22		
Valenciennes Viscose	0·19	0·24		
Strasbourg Viscose	0·23	0·15		
Viscose Suisse Emmenbrucke ...	0·23	0·73	1·50	
Rorschach Viscose	0·20	0·59		
Anversoise Viscose	0·50	0·17		
Obourg Viscose	0·23	0·43		
,, ,, ...	0·31	0·48		
Tubize Viscose	0·27	0·48		
,, ,, ...	0·19	0·46		
Japanese IV Cuprammonium ...	0·79	0·25	1·54	
Bemberg Cuprammonium ...	0·21	0·18		
,, ,, ...	0·21	0·48		
,, ,, ...	0·13	0·64		
Fr. Kuttner Cuprammonium ...	0·25	0·32		
,, ,, ...	0·20	0·45		
,, ,, ...	0·17	0·17		
Japanese IV Acetate	0·07	0·30	1·96	
Corona Wood Pulp	0·03	0·41	0·97	
V. S. Wood Pulp	0·31	0·38	1·52	
Kippawa Wood Pulp	0·30	0·35		

that points for all the samples examined lie on one or other of two curves (Fig. 1), so that the materials are divided into two broad classes. This behaviour is reflected by the values of ash alkalinity per gram of ash, which show that the Courtaulds' viscose rayons, Durafil, and Nuera Lilienfelds, and Vistra have low values of 10–14, while the remainder have values near to 20 or over. This may be explained by the fact that the ash of the materials of high ash alkalinity per gram of ash contains a larger proportion of substances, such as oxides, carbonates, etc., which are capable of neutralising dilute mineral acid, whereas the remainder are richer in such materials as silica or neutral salts like sodium sulphate.

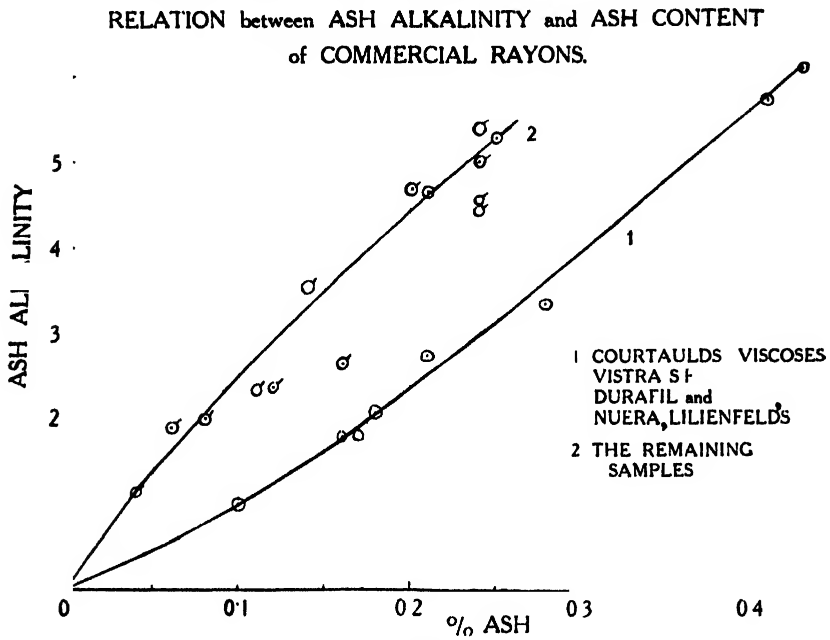

FIG. 1

Material Extractable by Solvents

Under this heading is included all material removed from the rayons under the conditions employed, irrespective of its composition, and no attempt has been made to analyse it into its components. Such material may be derived from the external dressings applied to the yarns after their manufacture, from oil incorporated in the filaments for delustring purposes (e.g. Dulesco and Dulenza yarns), from fat and wax residues from the wood pulp or cotton originally used, or from any other soluble or mechanically removable impurities. When mineral or other oil has been mixed with the viscose solution before spinning, it is impossible to remove it to any great extent by one extraction process such as that given in the present instance, but since the yarns were always treated with dilute mineral acid before extraction, all soap (part of which would otherwise have remained on the material) was removed. The solvents used were ether and chloroform, except for the acetate rayons, when only ether was employed, and the results obtained are collected in Table VI, while mean results for the ether extractions only are also given in Table I, facing p. T118. In general, the values obtained by extraction with chloroform are lower than those with ether,

exceptions to this being those for the Bemberg and Brysilka cuprammonium yarns. Table V, p. T131, shows the values obtained by Kami, but since no definite particulars of his treatment of the yarns is available, no strict comparison can be made between the sets of results here given. According to Kami, the "fat content" range is about 0·2–0·9% for all varieties, and the values vary according to the country of origin of the rayon; German and Italian yarns have low, and French and Swiss high values. The range now recorded for normal material that has not been dressed after manufacture is about 0·1–0·8%, and therefore agrees with that given by Kami, but the values for the Bemberg cuprammonium and the acetate yarns are considerably higher on account of oil, soap, etc., applied externally. As already mentioned above, the undesulphurised Tudenza viscose rayon also has a high value owing to the ease with which sulphur is removed from it mechanically during the extraction with solvent.

The lowest values obtained correspond with the fat and wax content of well-scoured cotton yarns, namely, 0·1–0·2%, and, indeed, figures lower than this are hardly to be expected.

Table VI

Extractable Material in Commercial Rayons, %

Variety	Ether	Chloroform
Viscose—		
"A" Quality	0·57, 0·57; mean 0·57	0·49
Escorto	0·21, 0·20, „ 0·21	0·17
Dulesco	0·67, 0·94; „ 0·80	0·63
Dulenza	0·54, 0·57; „ 0·56	0·57
Tudenza	1·37, 1·35; „ 1·36	1·28
Celta	0·31	—
Harbens	0·11, 0·12; „ 0·12	—
Obourg	0·09	—
Snia	0·15	0·12
Lilienfeld—		
Durafil	0·50, 0·48, „ 0·49	0·39
Tenasco (bleached)	0·24, 0·24; „ 0·24	0·18(unbleached)
Cuprammonium—		
Brysilka	0·25, 0·22; „ 0·24	0·32
Bemberg	2·01, 2·06, „ 2·04	2·93
I.G. Bemberg	2·64, 2·42; „ 2·53	—
Acetate-		
Seracceta (75 den., 1928)	2·00, 1·90, 2·02; mean 1·97	
Celanese (150 den., 1930)	2·00, 2·00, 2·00; „ 2·00	

Sulphur Content

The range found for desulphurised viscose and all other types of rayon is about 0·005 to 0·1%, with a mean value of 0·032%, while for the undesulphurised Tudenza viscose rayon the content is 0·35% (see Tables I and VII). Desulphurisation therefore appears to reduce the sulphur content to, quite roughly, a tenth of its original value for the undesulphurised unbleached material. Kami[16] has shown that the value for viscose rayons can never be reduced to zero by the use either of sodium sulphide or of ammonia solutions. If the latter are used in air-tight vessels, the content may be reduced to about 0·1%, which is lower than the minimum value for treatment with sodium sulphide, but no viscose rayons have been found

Table VII
Sulphur Content of Commercial Rayons

Variety	% Sulphur	Mean
Viscoses—		
Courtaulds' "A"	0·013, 0·012	0·013
,, Dulesco	0·030, 0·032	0·031
,, Dulenza	0·031, 0·036	0·033
,, Escorto	0·005	0·005
,, Tudenza	0·375, 0·381	0·378
Harbens'	0·010, 0·009	0·010
Snia	0·023	0·023
Obourg	0·021	0·021
Celta (hollow)	0·024, 0·021	0·023
Staple Fibre—		
I.G. Vistra	0·074	0·074
Courtaulds' Fibro	0·046, 0·045	0·046
Lilienfeld—		
Courtaulds' Durafil	0·023, 0·019	0·021
Nuera Tenasco	0·055, 0·061	0·058
Cuprammonium—		
Brysilka (old sample)	0·027, 0·021	0·024
,, "C" quality	0·006	0·006
Bemberg	Trace	Trace
Acetate—		
Courtaulds' Seraceta	0·034, 0·035	0·035
Celanese	0·052	0·052
Nitrocellulose—		
Obourg	0·097	0·097
Wood Pulp—		
Bleached	0·049, 0·050	0·050

Table VIII
Composition of Commercial Rayons
(Wahl and Rolland, *Rev. Gen. Mat Col.*, 1929, 33, 1-4).

Variety	Copper Number	% Sulphur	% Ash
Tubize (Nitro)	3·0	0·24	0·1–0·56% according to nature of rayon Celta (hollow filament), 0·30%
,, Marron Clair	2·93	0·33	
,, Gris Clair	3·11	0·41	
Valenciennes Viscose unbleached	0·85	0·26	
Viscose	0·96	0·39	
,, bleached	0·73	0·21	
Celta, unbleached	1·19	0·32	
,, dyed	0·85	0·28	
Chardonnet (old sample) ...	3·02	1·08	
Cuprammonium 60 den. ...	0·68	0·42	
,, 100 den. ...	0·51	0·20	
Wood Pulp—			
Swedish, bleached ...	2·5		
half bleached	2·0		
,, unbleached	1·2		
Sulphite, bleached	1·9		
,, unbleached	0·8		

from which sulphur is entirely absent. Kami's values (Table V) of about 0·03% are confirmed by the above, but the range given by Wahl and Rolland (Table VIII) of 0·2–0·4% is comparable only with that now found for undesulphurised viscose rayon. Obourg nitrocellulose rayon has the fairly high value of 0·1%, whilst those for Tenasco (Lilienfeld) and Celanese (acetate) yarns are somewhat higher than the normal figure for viscose rayons. Bemberg cuprammonium yarn made from cotton linters has a negligible sulphur content, whereas the 1928 quality Brysilka has the normal value for viscose rayons (0·02) and the 1930, C, quality contains only 0·006%, which is very low for a rayon prepared from wood pulp.

Copper Content

The values recorded in Table I are expressed as mgm. of metal per 100 gm. of dry material, and when it is seen that for the majority of samples they are less than 1 (i.e. the copper content is less than 0·001%, or 1 part in 100,000), it is realised how very small this content is. In these circumstances the mean results obtained by the three different methods used show as good agreement as can be expected, especially in view of the fact that absolute uniformity of metal content is hardly realisable in practice. Some of the values obtained in individual experiments varied between wide limits, especially with the 1928 quality of Brysilka, when, by the gravimetric method, results from about 1·5 to 26 mgm. per 100 gm. were obtained in ten experiments, with a mean of 9·1, although the mean of six, excluding the extreme values, was 7·4, which agrees well with the mean found by the colorimetric method. In others, and especially with the acetate samples, the variation between individual results was comparatively small.

It might be expected that the greatest values would be shown for cuprammonium rayons, but this is not so. It is true that the highest values recorded in Table I are for the 1928 Brysilka, but considerable improvements have recently been made in the manufacture of this material, as shown by the properties of the "W" and "C" qualities; the latter is the standard material now supplied, so that this and not the 1928 quality must be regarded as representative of this product.

The highest values, then, are given by the acetate and the Tenasco Lilienfeld rayons, for which the range is about 1·6 to 9 mgm. per 100 gm., while the mean value for normal desulphurised viscose rayons is 0·22, and that for the cuprammonium varieties (excluding the 1928 Brysilka) is 0·56. Courtaulds' Fibro staple fibre and Durafil Lilienfeld have values within the viscose range, and Vistra staple fibre has the slightly higher mean value of 0·82.

The catalytic effect of copper in accelerating chemical reactions increases with increasing amounts of the metal present, but since the amounts found in the varieties of rayon examined are so small (except for the 1928 Brysilka, and the Seraceta acetate and Tenasco Lilienfeld yarns) the danger of catalytic action during bleaching due to the presence of this metal may be considered negligible. Nevertheless there can be no doubt that efficient removal of copper from such yarns is highly desirable in order that the possibility of this action may be entirely excluded.

Iron Content

The iron content of the rayons examined varies within narrower limits than the copper content. The range is about 1 to 4·2 mgm. per 100 gm. of dry material, and this value is so small that effects due to the presence

of this metal must also be considered of no importance. Viscose yarns have the smallest content, about 0·7–2, while all the other varieties have values between 2·3 and 4·2, and the highest content is again shown by the 1928 Brysilka.

EXPERIMENTAL SECTION

Materials—The yarns employed are adequately described in the Introduction and Tables.

Sampling—A quantity in excess of that required for the experiments was taken from one or more hanks of the rayon, cut into 1-inch lengths, thoroughly mixed by hand, and sampled by the quartering method; sufficient material for both moisture determination and analysis was taken from it.

Moisture Content—Unless otherwise stated, in order to obtain the dry weight of material to be used in calculating the results, 0·5 gm. samples were weighed out at the same time as the amounts taken for analysis, and dried for three hours at 105–110° C. in an electric oven.

Methods of Measurement

Several of the analytical methods used have been described in previous publications from the Shirley Institute, to which brief references are given. In other determinations more or less well-known methods of analysis have been modified to suit requirements, and the experimental procedure is given in detail.

(1) *Copper Number*—The Schwalbe-Braidy method as examined by Clibbens and Geake[7] was used.

(2) *Methylene Blue Absorption*—This was determined on 2·5 gm. samples of air-dry rayon by the titrimetric method previously described,[3] except that a solution buffered to *p*H 7, as recommended by Clibbens and Geake,[8] was used.

(3) *Loss of Weight on Boiling with Alkali.*[4]

(4) *Fluidity in Cuprammonium Hydroxide Solution*—The method and apparatus described by Clibbens and Geake[9] were used, except that the concentration of cellulose in the solutions was 2% instead of 0·5%.

(5) *Acetic Acid Content of Acetate Rayons*—Both the Ost[18] and the Barnett[2] methods were employed.

(6) *Ash Content and Ash Alkalinity.*[3]

(7) *Material Extractable by Solvents*—The material was washed with acid and then with water, dried, and extracted, with ether in one series of experiments, and with chloroform in another, and the dry residues from the extracts were weighed.

(8) *Sulphur Content*—Samples of the rayon were ashed with concentrated hydrochloric and nitric acids, and the sulphate in the residue was precipitated and weighed as barium sulphate.

(9) *Copper Content*—Three methods of analysis were used for this measurement—(*a*) Direct precipitation of the metal as thiocyanate from a solution of the ash, and weighing as such[22]; (*b*) an indirect method, using as a measure of the copper content the catalytic effect of copper in accelerating the reduction of ferric salts by sodium thiosulphate solution[1,14]; and (*c*) the colorimetric method with diethyldithiocarbamate described by Callan and Henderson.[6]

(10) *Iron Content*—A modification of the method of Knop[17] was used, in which the metal, present in the ferrous state, was titrated with potassium dichromate solution, diphenylamine being used as indicator.

Experimental Procedures

Measurement of Fluidity.

The importance of the fluidity measurement as applied to cotton and chemically modified cotton is now quite generally recognised, so that the extension of this test to rayons of the regenerated cellulose type follows as a natural consequence. In this extension it is very desirable that the apparatus and experimental conditions employed for cotton materials as described by Clibbens and Geake[9] should be retained as far as possible, but whereas the fluidity of a 0·5% solution in cuprammonium of a well-scoured cotton under these conditions is about 1–3, and the time of outflow from the viscometer is about 15–20 minutes, that of a similar solution of a normal viscose rayon is 35–40, and the corresponding time of outflow is about one minute. The latter is much too short to be satisfactory when it is remembered that any slight overbleaching or acid attack of the rayon decreases the time of outflow still further, hence an alteration in the experimental conditions for rayon is necessary. As the alternative to modification of the standard viscometer, a change in the cellulose concentration of the solution is to be preferred, and the adoption of 2% for rayons instead of 0·5%, all other conditions remaining the same, has been found to give reasonably low values for the normal unmodified materials, and to allow of a convenient range of higher values for those that have suffered chemical attack. Thus, Table I shows that under these conditions the fluidity of normal viscose rayons is about 9–11·5—values that may be compared quite arbitrarily with the value 10 for cotton in 0·5% solution, which is tentatively accepted as the upper limit for technically bleached material—and figures in excess of this are indicative of overbleaching or attack by acids.

For the remaining varieties, other than nitrocellulose or acetate rayons, lower initial values are obtained; those for the nitrocellulose material are high but of minor importance, since this is seldom met with in British textile fabrics, and no values for acetate rayon are recorded because comparison between such values and those for all-cellulose materials is impossible owing to the difference in chemical composition of these types.

Results of a detailed investigation of the relation between fluidity and the tensile strength of rayon yarns will be published later.

Transfer of the rayon to the standard viscometer is facilitated by weighing the finely cut up material in a short piece of glass tubing open at both ends, instead of on a watch glass, inserting small corks in the ends to prevent loss while the remaining samples are being weighed, and then withdrawing the corks, placing the tube a short distance inside the upright viscometer, which is partly filled with cuprammonium solution, and pushing out the contents with a plunger formed from a piece of glass rod round the end of which a piece of rubber tubing is fixed so as to give a tight fit between it and the walls of the tube (see Fig. 2).

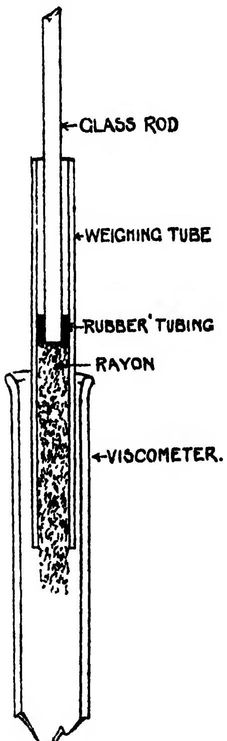

FIG. 2

In this way loss is avoided and the transfer is quickly and neatly accomplished. Further, if the same tube is always used with the same viscometer, its weight and that of the cellulose necessary to give a 2% solution in the particular viscometer can be recorded, and time is saved when a series of routine measurements is to be made.

Acetic Acid Content.

Ost's Method[18]—Samples of air-dry material weighing 0·5 gm., of known moisture content, cut up and separated as far as possible into individual filaments by brushing between two pieces of card-clothing, were treated in small tubes or stoppered flasks with 5 c.c. of 50% (volume) sulphuric acid for 20–24 hours at room temperature. The resulting liquid was diluted to 100 c.c. with water, transferred to the flask of a steam distillation apparatus, and subjected to distillation until, after 2–2½ hours, the last 50 c.c. of distillate required only one drop of 0·2*N* sodium hydroxide solution to develop the colour of the phenolphthalein indicator. The acetic acid content of the sample was calculated from the alkali titre, and expressed as grams of acid per 100 gm. of dry acetate rayon.

Barnett's Method[2]—One-gram samples of the finely divided, air-dry, material were dissolved in pure, redistilled acetone, 10 c.c. of 1*N* sodium hydroxide solution were added, the mixture was shaken continuously for some minutes to prevent gel formation, phenolphthalein indicator was added, and the whole allowed to stand at room temperature for 24 hours. After this time 10·5 c.c. of 1*N* sulphuric acid were added, the mixture was shaken during half an hour, and the excess of sulphuric acid was titrated with 0·1*N* sodium hydroxide solution. Blank experiments on the reagents in the absence of acetate rayon gave a mean value of 0·12 c.c. of the sodium hydroxide solution to be deducted from the above titre, and the percentage of acetic acid present was then found in the usual way.

Sulphur Content.

A micro-method for the determination of combined sulphuric acid in cotton has been elaborated by Clibbens and Geake,[11] but the method of ashing adopted by them—ignition of the cellulose material, previously wetted with a dilute solution of sodium carbonate, in a porcelain or silica crucible, is unsuitable for use with rayons when greater amounts of material are taken, first, because sulphur is sometimes present largely in the elementary condition or as compounds other than sulphate, and, secondly, because the use of sodium carbonate solution in amount sufficient to wet the material results in attack of the silica vessel during ashing, and in the formation during the subsequent operations of a silica gel which apparently retains sulphur somewhat tenaciously since lower values were always obtained when silica or porcelain vessels were used than when the ashing was performed similarly in a platinum dish.

The following procedure was therefore adopted and found to give reproducible results (see Table VII).

About 10 gms. of sampled material, in pellet form, were introduced into a 250 c.c. Kjeldahl flask, and 20 c.c. of pure concentrated hydrochloric acid were added from a measuring cylinder. When all the pellets were wetted, 60 c.c. of concentrated nitric acid were poured in, the flask was gently shaken and cautiously heated over the flame of a micro-burner until a homogeneous liquid was obtained. Shaking was continued at intervals during this time (about half an hour), and the liquid was then evaporated to small bulk, care

being taken to avoid charring. At this stage it was generally observed that a certain amount of mucilage and scum was present in the flask; this resisted further attack by the acids under the somewhat mild conditions of heating employed. The scum was specially noticeable with Dulesco and other yarns in which mineral or other oil was present either as a partial delustring agent or as a dressing, and it appeared to be connected with the presence of this oil. Substances such as vaseline and some oils give a somewhat similar scum on treatment with acids under these conditions. The mucilage, on the other hand, resulted from the degradation of the cellulose itself. In order to remove this material before precipitation of the sulphate, the contents of the flask, diluted with 20 c.c. of water, were washed into a centrifuge tube and centrifuged at a high speed for 10–15 minutes. The clear supernatant liquid was transferred to a beaker, the residue washed with boiling water and again centrifuged two or three times, and the washings were added to the contents of the beaker, whilst the residue was rejected. Sulphur was never detected in an elementary analysis of this residue.

The contents of the beaker, amounting to not more than 80 c.c. were heated to boiling, 5 c.c. of $0{\cdot}2N$ hydrochloric acid and 10 c.c. of a filtered and boiling $0{\cdot}1N$ solution of barium chloride were added, and the mixture was left to digest for two hours on the top of a steam oven. Finally, the precipitated sulphate was collected on a fine filter paper, washed, dried, and ignited in the usual way. Since ignition of the filter paper in contact with the precipitate causes reduction of some of the sulphate to sulphide, the residue was treated with 2–3 drops of concentrated sulphuric acid and reheated before cooling and weighing. The results obtained, expressed as grams of sulphur per 100 gm. of dry material, are given in Tables I and VII.

The Effect of Mercerisation on the Chemical Properties of Cotton

The processes concerned in the manufacture of rayons generally involve swelling of the cellulose to a greater or less degree, and it might be thought that this swelling, as distinct from chemical action, would be partly responsible for the higher values of such properties as fluidity, copper number, methylene blue absorption, and loss of weight on boiling with alkali of these materials as compared with those of normal, purified cotton. This, however, is very unlikely since, as already stated on p. T120, increasing the degree of dispersion of the cellulose by mercerising cotton with sodium hydroxide solutions, produces no significant increase in these properties, and there is no reason why the greater dispersion which obtains, for example, with viscose rayon should have such an effect. Evidence, in support of that already published, of the fact that mercerisation causes no increase in the above properties of cotton is given by the results of the following investigation.

Hanks of the cotton yarns specified in Table IX were given the same scour with 1% sodium hydroxide solution at 40 lb. excess pressure for six hours, washed with water, and centrifuged. Each hank was then cut in two, one set of halves was mercerised with $9N$-sodium hydroxide solution, without tension, and washed with hot water, and all portions were soured with hydrochloric acid and washed with distilled water until neutral. The moisture content of these air-dried samples was determined separately for each experiment, and measurement of the particular property was made on the cut-up and well mixed material. Fluidity measurements for the corresponding mercerised and unmercerised cottons were made in the same

viscometer in order to avoid slight variations due to the use of different instruments.

Results are given in Table IX, and it is shown that there is no significant increase in the respective values as a result of mercerisation. Slightly higher values for loss of weight on boiling with alkali are shown for some of the samples, but strict accuracy is hardly to be expected here owing to difficulties in manipulation, and to the fact that the loss is determined by finding a small difference between two relatively large weights.

Table IX

Effect of Mercerisation on the Chemical Properties of Scoured Cottons

Variety	Unmercerised				Mercerised			
	Fluidity	Copper Number	Methylene Blue Absorption	Loss of Wt. in Alkali Boil %	Fluidity	Copper Number	Methylene Blue Absorption	Loss of Wt. in Alkali Boil %
Egyptian Sakel	3·68	0·01	1·17	1·32	3·70	0·01	0·96	1·23
,, Uppers	3·38	0·01	1·10	1·20	3·34	0·01	0·95	1·31
Tanguis ...	3·47	0·015	1·24	0·84	3·42	0·01	1·09	1·28
Arizona ...	3·87	0·01	1·35	1·37	3·67	0·01	0·98	1·30
Peru Mitafifi	3·52	0·01	1·03	0·88	3·21	0·01	0·88	1·0

Many of the measurements recorded above were made by Mr. H. Bowden and Mr. H. S. Cliff.

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TRANSACTIONS

9—OBSERVATIONS ON THE SUSCEPTIBILITY OF ANIMAL FIBRES TO DAMAGE BY THE LARVÆ OF TWO SPECIES OF CLOTHES MOTH, *TINEOLA BISELLIELLA HUMMEL* AND *TINEA PELLIONELLA L.*

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(Wool Industries Research Association)

This paper is presented as a contribution to the facts which have accumulated through the medium of an extensive literature on the subject of clothes moths. It consists essentially of two series of observations which have been made on the behaviour of the larvæ of the common clothes moth (*Tineola bisselliella Hummel*) and the case-making clothes moth (*Tinea pellionella L.*) towards various kinds of raw and processed animal fibres. The effect of the presence of certain mothproofing substances and insecticides has also been noted.

SERIES A—THE SUSCEPTIBILITY OF WOOL AND OTHER TEXTILE MATERIALS TO ATTACK BY THE COMMON CLOTHES MOTH UNDER NATURAL CONDITIONS

These observations arose as the result of an occurrence of attack by the common clothes moth (*Tineola bisselliella Hummel*) on a number of specimen samples of wool which had been stored in two loose-leaf folders for 12 months under ordinary household conditions. Each page of the folders contained from two to eleven specimens the thickness of which was sufficient to cause a separation of adjacent pages, thus allowing the adult moths or larvæ to gain access to them. In the subsequent examination of the materials, larval activity, where present, was evidenced by the appearance of excreta, cocoon silk or actual damage to the fibres.

The folders also contained a number of specimen fibres which were of vegetable origin.

A description of the samples taken in order of their position in the folders, and the observations obtained are set out in Table I.

Table I

Page of Folder	No. of Sample	Type of Material	Remarks on Sample	Observations
I (1)	1	Long Wool	Fleece	Slightly damaged
	2	Mohair	White	Badly damaged
	3	Short Botany ...	Fleece	Slightly damaged
	4	Alpaca	Black...	Badly damaged
	5	,, ...	White	,, ,,
	6	,, ...	Brown	Slightly damaged
	7	Silk	Spun Thread ...	Not attacked
	8	Camel Hair	... ...	Badly damaged
	9	Cashmere	Grey	Very badly damaged
	10	Tussah Silk	... ...	Not attacked
(2)	11	Flax	Scutched fibre ...	Not attacked
	12	Hemp	Retted	,, ,,
	13	Ramie	Sliver...	,, ,,
	14	Paper	Yarn	,, ,,
	15	Egyptian Cotton ...	Raw	,, ,,
	16	Marine Fibre ...	... ...	,, ,,
	17	Capok	... ...	,, ,,

Table I—*continued*

Page of Folder	No. of Sample	Type of Material	Remarks on Sample	Observations
(3)	18	Shropshire Noil ...	... ...	Not attacked
	19	Shoddy	... ...	,, ,,
	20	Spinning Waste ...	... ...	Slightly damaged
	21	Botany Noil ...	... .	Not attacked
	22	Mungo	... ...	,, ,,
	23	Shoddy Noil ...	Dyed	Slightly damaged
	24	Mohair Noil	... ...	Badly damaged
	25	Extract	... ...	Not attacked
	26	Blended Mungo ...	... ...	,, ,,
(4)	27	Scotch Black Face ...	Unscoured	Slightly damaged
	28	Lincoln Hog ...	,, ...	,, ,,
	29	Lincoln Wether ...	,, ...	,, ,,
(5)	30	Wensleydale Hog ...	Unscoured	Badly damaged
	31	Wensleydale Wether	,, ...	,, ,,
	32	Romney Hog ...	,, ...	,, ,,
	33	Romney Wether ...	,, ...	Slightly damaged
(6)	34	Wether Wool ...	Unscoured	Slightly damaged
	35	Hog Wool	,, ...	,, ,,
	36	Down Teg	,, ...	Badly damaged
	37	Down Wether ...	,, ...	Slightly damaged
(7)	38	Shetland	Brown, unscoured ...	Slightly damaged
	39	,, ...	White, ,, ...	,, ,,
	40	,, ...	Grey, ,, ...	Badly damaged
(8)	41	46's Britch F.C.* ...	FleeceWool,unscoured	Slightly damaged
	42	50's Back F.C.* ...	,, ,, ,,	,, ,,
	43	40's/44's Back M.C.†	,, ,, ,,	Badly damaged
	44	50's Back F C.* ...	,, ,, ,,	,, ,,
(9)	45	46's Shoulder, Irish Wool	Unscoured	Slightly damaged
	46	,, ,, ,,	,, ...	Badly damaged
	47	40/44's Britch ,,	,, ...	Very slightly damaged
	48	50's Back ,,	,, ...	,, ,,
(10)	49	44's Irish Wool ...	Unscoured	Slightly damaged
	50	46's ,, ,, ...	,, ...	Not attacked
	51	48's ,, ,, ...	,, ...	Slightly damaged
	52	50's ,, ,, ...	,, ...	,, ,,
(11)	53	Fine Merino (unscoured)	Port Phillip	Badly damaged
	54	,, ,, ,,	West Australian ...	Slightly damaged
	55	,, ,, ,,	Melbourne	Badly damaged
	56	,, ,, ,,	Brisbane	Fairly badly attacked
	57	,, ,, ,,	Sydney	,, ,, ,,
	58	,, ,, ,,	Tasmanian	,, ,, ,,
(12)	59	Fine Merino (unscoured)	60's ...	Badly damaged, but particularly at the tips
	60	,, ,, ,,	64's Very ...	,, ,, ,,
	61	,, ,, ,,	64's heavy in ...	,, ,, ,,
	62	,, ,, ,,	64's natural ...	,, ,, ,,
	63	,, ,, ,,	64's grease ...	,, ,, ,,
	64	,, ,, ,,	64's ...	,, ,, ,,
	65	,, ,, ,,	64's ...	,, ,, ,,
	66	,, ,, ,,	64's ...	,, ,, ,,
	67	,, ,, ,,	64's ...	,, ,, ,,

*F.C. = Fine Crossbred. †M.C. = Medium Crossbred.

Table I—*continued*

Page of Folder	No. of Sample	Type of Material	Remarks on Sample	Observations
(13)	68	Cape Mohair... ...	3's Quality	Fairly badly damaged, chiefly at the tips
	69	,, ,, ...	2's ,, ...	,, ,, ,,
	70	,, ,, ...	3's ,, ...	,, ,, ,,
	71	,, ,, ...	2's ,, ...	,, ,, ,,
	72	,, ,, ...	6's ,, ...	,, ,, ,,
	73	,, ,, ...	6's ,, ...	,, ,, ,,
(14)	74	Turkey Mohair ...	2's Quality	Fairly badly damaged
	75	,, ,, ...	3's ,, ...	,, ,, ,,
	76	,, ,, ...	4's ,, ...	Slightly damaged
	77	,, ,, ...	5's ,, ...	,, ,,
	78	,, ,, ...	6's ,, ...	Badly damaged
(15)	79	Low Alpaca	Black...	Badly damaged
	80	,, ,, ...	Brown	,, ,,
	81	,, ,, ...	Black...	,, ,,
	82	,, ,, ...	White	Very badly damaged
	83	,, ,, ...	Grey	Badly damaged
	84	,, ,, ...	,, ...	Slightly damaged
(16)	85	Cotton	Nine samples, Egyptian and Sea Island	No evidence of attack
(17)	86	Shoddy	Pulled	No evidence of attack
	87	,, ...	Carded Web ...	,, ,, ,,
	88	,, ...	Slubbing	,, ,, ,,
	89	,, ...	Spun Yarn	,, ,, ,,
	90	Mungo Series I ...	Raw Blend	,, ,, ,,
	91	,, ,, ...	Carded Web ...	,, ,, ,,
	92	,, ,, ...	Slubbing	,, ,, ,,
	93	Mungo Series II ...	Raw Blend	,, ,, ,,
	94	,, ,, ..	Carded Web ...	,, ,, ,,
(18)	95	Jute	Eight samples, including retted, scutched, yarn and Hessian	No evidence of attack
(19)	96	Hemp	Eight samples selected from various stages of manufacture	No evidence of attack
II (1)	97	40's prepared English	Top	Not attacked
	98	50's Down	,, ...	Very slightly damaged
	99	56's Crossbred ...	,, ...	,, ,, ,,
	100	64's Botany	,, ...	,, ,, ,,
(2)	101	32's Crossbred ...	Top	Very slightly damaged
	102	36's ,, ...	,, ...	,, ,, ,,
(3)	103	32's Crossbred ...	Top	Very slightly damaged
	104	36's ,, ...	,, ...	,, ,, ,,
	105	40's ,, ..	,, ...	,, ,, ,,
	106	46's ,, ...	,, ...	,, ,, ,,
(4)	107	32's Crossbred ...	Top	Very slightly damaged
	108	46's ,, ...	,, ...	Not attacked

Table I—*continued*

Page of Folder	No. of Sample	Type of Material	Remarks on Sample	Observations
(5)	109	28's Crossbred ...	Top	Not attacked
	110	44's ,, ...	,, ...	,, ,,
(6)	111	58's Comeback Wool	Top	Very slightly damaged
	112	60's ,, ..	,, ...	,, ,, ,,
(7)	113	64's Botany	Top	Very slightly damaged
	114	80's ,, ...	,, ...	Not damaged
	115	70's ,, ...	,, ...	,, ,,
(8)	116	64's Cape	Top	Not attacked
	117	70's ,, ...	,, ...	,, ,,
	118	64's Australian ...	,, ...	Very slightly damaged
(9)	119	Mohair 3's Qu.Turkey	Top	Not attacked
	120	,, 4's ,, ,,	,, ...	,, ,,
	121	,, 3's Qu. Cape	,, ...	Very slightly attacked
	122	,, 4's ,, ,,	,, ...	,, ,, ,,
(10)	123	Mohair 5's Qu.Turkey	Top	Not attacked
	124	,, 6's ,, ,,	,, ...	,, ,,
	125	,, 5's Qu. Cape	,, ...	,, ,,
	126	,, 6's ,, ,,	,, ...	,, ,,
(11)	127	Alpaca 3's Quality ...	Top Fawn and Grey	Not attacked
	128	,, 4's ,, ...	Top Brown	,, ,,
	129	,, 6's ,, ...	,, ,, ...	Badly attacked
(12)	130	Crossbred Wool ...	Nine samples selected from stages in the drawing and spinning processes	Two samples slightly attacked
(13)	131	Botany Wool	Eleven samples selected from stages in the drawing and spinning processes	Three samples slightly attacked
(14)	132	Mohair	Nine samples selected from stages in the drawing and spinning processes	Three samples slightly damaged
(15)	133	Mohair	Seven samples of yarn (2/12's to 2/40's) undyed	Not attacked

It will be seen that evidence of moth activity was present on one or more of the samples comprising 26 of the total of 34 sets. Of the remaining eight sets, four consisted of vegetable fibres which according to Clark[3] would not be expected to be attacked by the larvæ, while the rest comprised animal fibres in processed and partly processed forms, including remanufactured materials.

According to Clark the adult moth is unable to select for the purpose of egg deposition, the most suitable food for the larvæ. Hence primary infection by the adult moth would have been a matter of chance. In any case it was impossible to ascertain the amount of infection due to the original source and that due to the subsequent migration of the feeding larvæ or to later generations of adult moths. In addition, no information was available as

to the time the materials had been infected, so that any conclusion which might be drawn from the examination must be regarded with reserve.

The most interesting features observed were the following—

(1) None of the samples of vegetable origin or the silks were attacked.

(2) Of the fleece wool fibres containing natural grease, most of the merino and the hair samples were badly attacked, while the crossbred samples, in general, were damaged only to a moderate degree.

(3) Of the prepared, that is, partly manufactured, wools and hairs, the general tendency was for them to have sustained only a slight degree of damage.

(4) The samples of manufactured wool containing 15% or more of added oil were not affected at all.

(5) The samples of raw merino wool and mohair affixed respectively to pages 12 and 13 were particularly interesting in that they suffered attack principally at the tips. These samples were very heavy in natural grease.

The general conclusion which, with reservation, might be drawn was that while the naturally greasy wool showed the greatest amount of damage, processed wools containing greasy matter of vegetable origin were only slightly affected. Where vegetable oils or oleins were present in quantity, as in the woollens, evidence of larval activity was absent.

SERIES B—THE ACTION OF THE CASE-MAKING CLOTHES MOTH UNDER CONTROLLED CONDITIONS

This series comprised five sets of experiments, viz.—

(1) The effect on the behaviour of larvæ in the presence of three optional sources of animal fibres selected indiscriminately.

(2) The behaviour of larvæ towards alternative sources of food differing in specific characteristics.

(3) The effect of the presence of fatty acids and mineral oils.

(4) The effect of treatment with the proprietary mothproofing agents "Larvex" and "Eulan."

(5) Experiments with volatile insecticides.

In all cases the materials have been exposed to the action of the larvæ of the case-making clothes moth, *Tinea pellionella*, this species being chosen for convenience of handling. In preparing the larvæ used for inoculation, care was taken to select only those which were more than half to almost fully grown and showed actual movement. Incubation was carried out in a dark room at 23° C. and about 70–80% relative humidity.

(1) The Effect on the Behaviour of Larvæ of the Presence of Three Optional Sources of Animal Fibres Selected Indiscriminately

Thirty-six samples of raw and processed wool, each weighing about 1 g. were divided at random into groups of three. Each group was then placed in a cubical tin of 3 in. side together with six active larvæ and a small portion of infected alpaca. After six weeks, 11 additional living larvæ were placed in each tin. At this point also, 22 other samples were incubated under similar conditions in seven tins, the last tin receiving four samples. All the samples were examined for evidence of damage after a further period of 24 weeks. The grouping of the varieties and the observations made are described in Table II.

Table II

No of Tin	No of Sample	Type of Material	Remarks on Sample	Extent of Damage and other Observations
61	1	Lima Fleece		Appreciable
	2	40's Prepared English Top		Very slight
	3	50 s New Zealand Fleece	Very heavy in grease	Appreciable
62	4	French Scoured Skin Merino		Fairly bad
	5	64 s Cape Top	.	Slight
	6	50 s New Zealand Fleece	Very light in grease	Very bad, only a small portion left
63	7	Iceland Fleece	Washed (White Southern Class 1)	Very slight
	8	Peruvian Goat Hair		Appreciable
	9	Low Union Cloth No 1	Claimed by makers to be mothproof	Very slight
64	10	Yellow Egyptian Fleece		Bad
	11	Botany Noil		Very slight
	12	Low Union Cloth No 2	Claimed by makers to be mildewproof	No definite evidence of attack
65	13	Spanish Crossbred Fleece		Very bad
	14	Romney Hog Fleece		Fairly bad
	15	Low Union Cloth No 1	As sample No 9	None
66	16	Spanish Wool Fleece	Containing 10/12% lambs wool	Fairly bad
	17	Cape Mohair No 6	..	Very bad Almost completely disappeared
	18	50 s Carded Top	In oil	Slight
67	19	East Indian White Kandahar Fleece		Very bad Completely disappeared
	20	Mungo		No definite evidence of attack
	21	46 s Prepared Top	In oil	Slight
68	22	Chile Wool Fleece		Fairly bad
	23	Brown Alpaca	...	Very bad Only a small portion remains
	24	60 s Worsted Cloth	Scoured	Bad Many holes and thin places

Table II—*continued*

No. of Tin	No. of Sample	Type of Material	Remarks on Sample	Extent of Damage and other Observations
69	25	Low Canadian Cross-bred Fleece	Sample was seedy ...	Very bad. Completely disappeared
	26	40-44's Britch Fleece	... ...	Appreciable
	27	1/24's Worsted Yarn	Containing a little oil	Very bad. Only a small portion left
70	28	Low Canadian Cross-bred Fleece	... ...	Appreciable
	29	Shoddy Noil ...	Sample was dyed ...	No definite evidence of attack
	30	Crossbred Top ...	Containing oil (2621 A., Vickers)	Slight
71	31	Fine Canadian Cross-bred Fleece	... ...	Very bad. Sample almost completely disappeared
	32	Mungo	... ...	Fairly bad
	33	Worsted Cloth ...	Containing 0·7% olive oil	Bad, though less damaged than Sample No. 24
72	34	Canadian Merino Fleece	... ...	Very bad, only a small portion remains
	35	Shoddy	... ...	Very bad. Completely disappeared
	36	Worsted Cloth ...	Containing 0·5% added wool fat free from fatty acids	Slight (removed after six weeks; see No. 54)
54	37	Human Hair (Chinese Stump)	... ...	Bad
	38	German Half-bred Fleece	... ...	Fairly bad
	39	East Indian Fawn "Joria" Fleece	... ...	Very bad. Almost completely disappeared
55	40	Iceland Skin Wool ...	... ...	Slight
	41	Black Turkish Goat-Hair	... ...	Appreciable
	42	Hair Blend	Low Morley Woollen	No definite evidence of attack
56	43	Grey Turkish Goat Hair	... ...	Very bad. Only a small portion remaining
	44	Red Turkish Mohair	... ...	Very bad. Sample completely disappeared
	45	Botany Tops	Containing little oil...	Appreciable

Table II—*continued*

No. of Tin	No. of Sample	Type of Material	Remarks on Sample	Extent of Damage and other Observations
57	46	Grey China Clipped Mohair	... ...	Very bad. Sample completely disappeared
	47	44's Roving	... .	Slight
	48	Hosiery Fabric ...	Finished with peroxide and rendered unshrinkable by chlorination	Fairly bad
58	49	Undyed Flannel ...	Slightly over chlorinated	Slight
	50	Billiard Cloth ..	In the grey (unscoured) The size contained salicylic acid	None
	51	Billard Cloth . .	Dyed and finished .	Appreciable Much of the pile removed
59	52	Low Union Cloth No. 2	As sample No 12 ...	Appreciable Much of the pile removed
	53	Low Union Cloth No. 1	As sample No 9 .	Slight Some of the pile removed
	54	Worsted Cloth ..	Containing wool fat. (Sample No. 36)	Appreciable One or two holes in the cloth
60	55	Undyed Flannel ...	As sample No 49 but not chlorinated	Bad Several large holes in the cloth
	56	Fine Saxony Slubbing	Containing about 10% oil (Vickers 2130)	No definite evidence of attack
	57	Cape Slubbing (Black and White)	Containing about 10% olive oil	No definite evidence of attack
	58	64's Slubbing . .	Dyed light blue, containing about 10% oil (Vickers 2130)	No definite evidence of attack

As before mentioned, no discrimination whatever was made in the grouping of the samples, the experiment being conducted independently of the broad conclusions suggested by the first series of observations. Nevertheless, with a few exceptions, the same interesting feature regarding the comparatively unpalatable nature of materials containing greater or less quantities of added fatty material of vegetable origin was emphasised.

The majority of the samples were not exposed in duplicate. Consequently in this case also, the various points of interest which arose from the observations must not be regarded as conclusive. Omitting the reference to the action of vegetable lubricants, these points were as follows—

(1) Over-chlorinated flannel, as illustrated by sample No. 49, offered greater resistance to attack than similar material which had not been chlorinated (sample No. 55). On the other hand, normally chlorinated hosiery fabric (sample No. 48) was fairly badly attacked.

(2) Billiard cloth in the grey, the warp threads of which were sized with "Flourine" and contained salicylic acid as a mildew preventative, was not attacked, whereas the dyed and finished fabric had a considerable portion of pile removed (samples Nos. 50 and 51).

(3) The Low Union cloth (samples Nos. 9, 12, 15, 52, and 53) offered considerable, but not, in all cases, complete resistance to larval attack. Variety No. 1 is claimed by the manufacturer to be mothproof and variety No. 2 mildewproof.

(2) The Behaviour of Larvæ in the Presence of an Alternative Source of Food

A small quantity (about 0·1 g.) of the material under test together with or without a similar amount of an alternative kind of wool was placed in a test tube and inoculated with six larvæ of *Tinea pellionella*. The experiments were made in duplicate, the contents of each tube being examined at intervals when more larvæ were added to replace those which had pupated.

For describing the nature of damage observed in this and the following experiments, an arbitrary system of rating on the basis of 9 and expressing the average of the two results, has been adopted. This method of classification is subject to the personal equation and thereby entails many disadvantages, the chief being that it does not express the smaller differences in the appearance of the various materials. It serves, however, to present the general trend of larval activity which is perhaps of more importance in view of the qualitative nature of the tests themselves. The units of this rating given in Tables III, IV, and V, are as follows—

0=Fabric not attacked.
1=Fabric very slightly attacked.
2=Fabric slightly attacked.
3=Fabric fairly badly attacked.
4=Fabric badly attacked.
5=Fabric very badly attacked.
6=Fabric destroyed to the extent of about one-half of its weight.
7=Fabric almost completely consumed.
8=Fabric completely consumed.

In this particular series the results are qualified by additional remarks appertaining to the differences observed.

Table III

No	Type of Material	Observations 5 weeks	19 weeks	28 weeks	Additional Remarks
1	Flannel Blend (carded) containing 6% oil	1	2	2	
2	60's Flannel Blend (carded) containing 6% oil	1	1	2	Preference for natural wool
	English III Felting Wool (super Shrop wether) (greasy)	1	3	6	
3	English III Felting Wool (super Shrop. wether) (scoured)	3	6	7	

Table III—*continued*

No	Type of Material	Observations 5 weeks	19 weeks	28 weeks	Additional Remarks
4	English III Felting Wool (super Shrop wether) (scoured)	6	7		Preference for scoured wool
	Do (greasy)	3	4	—	
5	English VIII Felting Wool (scoured)	2	4		
6	English VIII Felting Wool (scoured)	3	6		Preference for scoured wool
	Do (greasy)	3	4		
7	English VIII Felting Wool (scoured)	2	5	7	
8	English VII Felting Wool (scoured)	3	5	6	Preference for scoured wool
	Do (greasy)	3	4	5	
9	56's Australian Fleece (8.5% grease)	1	2	2	Grease content had no special influence
	Do (13.3% grease)	1	2	2	
10	60's Australian Fleece (10.4% grease)	1	2	2	Slight preference for greasy wool
	Do (12.7% grease)	1	2	2	
11	Canary Discoloured Wool W. Australian (scoured in benzene)	2	5	7	
12	Canary Discoloured Wool W. Australian (scoured in benzene)	2	3	3	Slight preference for scoured wool
	Do (unscoured)	1	2	2	
13	Cashmere Yarn	1	3	8	
14	Cashmere Yarn	1	3	7	Preference for natural fibre
	White Cashmere (raw)	2	6	7	
15	2/39's Unscoured Yarn	1	1	2	
16	2/39's Unscoured Yarn	1	1	2	Preference for fleece wool
	58's Tasmanian Fleece	2	3	3	
17	50's Punta (dry combed)	1	7	8	
18	50's Punta (dry combed)	1	3	5	Preference for fleece wool
	44's Top in olive oil	1	2	3	
19	50's Punta (dry combed)	1	4	7	Preference for fleece wool
	Botany Top containing 2.5% olive oil	1	3	4	
20	Botany Top (dry combed)	1	5		
21	Botany Top (dry combed)	2	7	8	Distinct preference for dry combed top
	Botany Roving containing 2.9% olive oil	1	3	5	
22	Botany Top (dry combed)	2	3	5	Preference for dry combed top
	Botany Roving containing 2.7% olive oil substitute	1	3	4	
23	Woollen Yarn containing about 15% oleine	1	3	3	

Table III—*continued*

No.	Type of Material	Observations 5 weeks	19 weeks	28 weeks	Additional Remarks
24	Woollen Yarn containing about 15% oleine	—	1	2	Preference for the worsted yarn
	60's Botany Yarn in oil	1	3	4	
25	Camel Hair Fabric	2	6	7	Pile first attacked
26	Camel Hair Fabric	1	3	6	Preference for natural fibre
	Camel Hair (China) (raw) ...	2	5	8	
27	Black Alpaca Top (in oil) ...	1	2	2	
28	Black Alpaca Top (in oil) ...	2	3	7	Preference for natural fibre
	Black Alpaca (raw)	2	6	7	
29	Goat Hair Yarn (in oil)	2	3	5	
30	Goat Hair Yarn (in oil)	1	2	2	Preference for natural fibre
	Grey Goat Hair (Chinese) (raw) ...	3	4	7	
31	24's Mohair Warp (sized with glue size)	2	3	3	
32	24's Mohair Warp (sized with glue size)	1			Slight preference for unsized yarn
	Do (not sized)	1			

The preference shown by larvæ for fibres in their natural condition was again a conspicuous feature of the results, particularly in the case of camel hair, alpaca, goat hair and cashmere. Natural sheep's wool was also more liable to attack than processed wool containing vegetable oil. Preference was also shown for worsted yarn in oil in the presence of woollen yarn having a high olein content whilst the latter was fairly badly attacked when no other choice of food was offered. Variation in the grease content of merino fleece wool did not appear to influence the larvæ to any appreciable extent.

Another item of importance was that scouring of natural sheep's wool with soap, without addition of oil, further enhanced the tendency to damage. When this observation is brought into line with the fact that scoured fleece wool is more attractive to moth larvæ than white wool fabric, as reported by White, Fulton, and Cranor,[7] the necessity for special vigilance during storage of this material becomes evident.

Other features of minor importance were that the sizing of mohair with glue size and the oiling of botany roving with an olive oil substitute containing a little mineral oil gave slightly better protection than unsized mohair and roving treated with pure olive oil respectively.

(3) The Effect of the Presence of Fatty Acids and Mineral Oils

Returning to the observations made with respect to wool materials containing vegetable oil, the extent to which they are borne out by trade experience is not known, although it is believed that instances of such goods

being moth eaten are comparatively rare. As a case in point it might be mentioned that in 1923 a member of this Association, in describing the damage caused in Egypt by the grubs of the Dermestid beetle, *Anthrenus fasciatus*, stated that these insects do not seem to attack yarn when in oil, but only when scoured or white genapped and finished.

A statement to the same effect has since been made personally by a textile official of the Egyptian Government.

A possible explanation of the phenomenon in question is to be found in a paper by Minaeff and Wright[6] of the Larvex Corporation, published during the course of the preceding experiments. These workers, while checking the validity of a statement specified by Jackson and Wassel[4], demonstrated that flannel treated with certain quantities of oleic acid showed considerable resistance to larval attack. No details were adduced, however, as to the manner in which the effect was brought about. In a supplementary patent Jackson and Wassel[5] claimed to have discovered that fatty acids have insect-repelling and particularly mothproofing properties. They also stated that a solution of quinidine oleate containing 1% calculated as quinidine is effective against the attack of clothes moths on wool.

Whatever the contributory value of the fatty acids may be when applied in this manner, it is highly improbable that they could be employed in the free state, especially since cases of moth larvæ attacking woollens containing exceedingly large quantities of olein have been noted.

Nevertheless, it was considered that a few experiments on the influence of fatty acids on the action of *Tinea pellionella* would not be out of place. In addition to these tests the effect of mineral oils was also investigated.

Portions of 60's quality scoured worsted cloth treated with emulsions of fatty acids or mineral oils were exposed in plugged test tubes to the action of six larvæ and the effects compared with those observed from a similar series in the presence of untreated cloth. The tubes were examined at intervals of a few weeks, additional larvæ being added as before. The test was made in duplicate. (See Table IV.)

It will be observed that the lower values for all the fatty acids did not give protection against injury. When, however, untreated cloth was also present the larvæ showed, in general, a distinct preference for it.

The addition of larger quantities of fatty acids produced, in most instances, a considerable degree of protection while the preference for untreated wool was still more marked, except in the case of the lower members of the acid series.

The lower values for the mineral oils considerably checked the amount of damage whilst the higher quantities, apart from one exception, prevented it entirely. The portions of untreated wool exposed with those containing the larger quantities of oil were affected to practically the same extent as the control sample, thus indicating that the mere presence of cloth containing mineral oil presents no barrier to the action of grubs on wool which is free from it.

The reason for the repelling action of wool containing vegetable oil offers a problem to the physiological zoologist. It may be that the fatty acid constituent renders the goods distasteful to the larvæ, although a more

Table IV

*Treatment		Condition of Cloth after Exposure: Treated Cloth only, 4 weeks	11 weeks	18 weeks	†	Treated and Untreated Cloth, 4 weeks	11 weeks	18 weeks
1% Palmitic acid	(0·64)	2	3	4	*a*	2	3	3
					b	2	5	5
5% „ „	(4·6)	0	1	1	*a*	0	1	1
					b	2	4	5
1% Myristic acid	(0·57)	2	2	4	*a*	1	2	3
					b	2	3	3
5% „ „	(5·2)	1	2	2	*a*	1	2	3
					b	3	5	5
1% Stearic acid	(0·57)	2	3	5	*a*	2	2	2
					b	2	3	3
5% „ „	(3·3)	2	4	5	*a*	1	2	2
					b	3	4	4
1% Lineolic acid	(0·56)	2	4	5	*a*	1	2	2
					b	2	2	3
5% „ „	(5·5)	0	0	1	*a*	0	0	0
					b	1	2	2
1% Erucic acid	(0·68)	2	3	5	*a*	1	2	2
					b	3	4	4
5% „	(2·8)	2	3	5	*a*	1	2	2
					b	2	5	5
1% Oleic acid	(0·50)	2	3	4	*a*	1	2	4
					b	2	4	5
5%	(4·4)	0	1	2	*a*	0	0	0
					b	2	3	4
1% Caproic acid	(0·62)	2	4	5	*a*	2	3	4
					b	2	3	3
5% „	(3·3)	0	0	0	*a*	2	2	3
					b	1	2	2
1% Caprylic acid	(0·64)	1	2	3	*a*	2	3	4
					b	2	3	4
5% „ „	(4·3)	2	3	3	*a*	1	1	1
					b	1	1	2
1% Lauric acid	(0·72)	2	2	4	*a*	2	2	3
					b	2	3	3
5% „ „	(2·7)	0	1	2	*a*	1	2	2
					b	2	3	3
1% Liquid paraffin	(0·57)	1	3	4				
5% „ „	(3·7)	0	0	0	*a*	0	0	0
					b	2	4	4
1% ABW Spotless machinery lubricant	(0·75)	1	2	3				
5% „ „	(3·3)	0	0	0	*a*	1	1	1
					b	3	3	3
1% JAY Spotless machinery lubricant	(0·63)	1	1	1				
5% „ „	(2·9)	0	0	0	*a*	0	0	0
					b	2	3	3
1% Scotch oil (pale)	(0·51)	1	2	3				
5% „ „	(3·8)	0	0	0	*a*	0	0	0
					b	2	4	4
Control (no treatment)		2	3	5				

* Fatty acids applied with water and emulsified with a little ammonia Mineral oils applied as emulsion in weak soap solution.

† *a* = Treated *b* = Untreated cloth.

favourable suggestion is that the comparatively mobile oil adheres to the outer covering of the grub, thereby clogging its respiratory pores.

Whatever the cause, it is evident that the properties of vegetable oils differ essentially from those of natural fibres in this respect. In the case of raw wools, however, the suint or other inherent factor may contribute to their relatively greater attractiveness whilst the actual fatty compounds may exercise no such property. The very greasy samples of merino fleece listed in Table I, Nos. 59–67, were particularly attacked at the tips. It is possible that some additional factor may be present in those portions. It is of interest here to note that the grease content of those animal wools which appear to be most favoured by the clothes moth larvæ, namely alpaca, camel hair, and cashmere, is comparatively small, whereas in the case of sheep's wool, the observations made in the previously described tests suggest that the removal of the natural grease by soap scouring increases the susceptibility to attack.

(4) The Effect of Treatment with the Proprietary Mothproofing Agents—"Larvex" and "Eulan"

This test was carried out in the same manner as that previously described. The "Eulans" were applied in accordance with the maker's instructions and "Larvex," which was described as the "Rinsing" brand, in various concentrations, including that of 2% recommended by the makers. (See Table V.)

Table V

Treatment	Condition of Cloth after Exposure					
	Treated Cloth only				Treated and Untreated Cloth	
	4 weeks	11 weeks	18 weeks	†	4 weeks	10 weeks
Larvex 0·1%*	2	2	3			
,, 0·2%*	2	3	3			
,, 0·3%*	2	2	2			
,, 1%*	0	0		*a*	0	0
				b	0	0
,, 2%*	0	0	–	*a*	0	1
				b	1	2
,, 4%*	0	0		*a*	0	0
				b	0	0
Eulan extra	0	0	0	*a*	0	0
				b	2	3
,, ,, (applied at boil)	0	0	0	*a*	0	0
				b	1	2
Eulan F	0	0	0			
,, (cloth well rinsed after treatment)	0	0	0	*a*	1	3
				b	3	5
Eulan W extra	0	0	0	*a*	0	0
				b	0	0
Eulan N	0	0	0	*a*	0	
				b	2	
Control (no treatment)	2	3	5			

* Immersed 15 minutes in solutions containing these quantities, calculated on the weight of wool.

† *a* = Treated cloth. *b* = Untreated cloth.

These observations left little doubt that at least as far as unscoured worsted cloth is concerned, the claims made by the manufacturers of these substances are justified.

The effect of the presence of untreated cloth on the behaviour towards the treated, and vice versa, depends in all probability on which particular sample the larvæ first focus their attention. As far as is known the grubs possess neither sight nor olfactory sense[3] so that their selection of food is purely accidental, being conditioned solely by contact. Hence it is feasible to expect that extensive damage may sometimes occur to unproofed cloth in the presence of proofed material; as evidenced by the experiment with Eulan Extra and Eulan F (rinsed). On the other hand, damage to Eulan proofed wool in the presence of untreated fabric, as shown chiefly by the Eulan F (rinsed) test is more difficult to explain, although it is not claimed that this substance is fast to washing.

Subsequent tests with the larvæ of *Tinea bisselliella* on wool materials treated with Eulan Extra and the recently introduced brand Eulan NK have given adequate proof of the efficacy of these substances. The larvæ caused a small amount of damage, but their activities were short lived. Under general conditions of storage, a spontaneous infection of wool with almost fully developed and voracious larvæ as used in these tests is unlikely. Infection usually takes place through the deposition of eggs by the female moth. The newly hatched and minute larvæ are much more sensitive to adverse conditions and particularly to the presence of poisons such as Eulan.

It is understood that Eulan Extra and Eulan F are now no longer procurable.

It is not proposed here to discuss the relative merits of Larvex and the Eulans, although it may be of interest to note that according to Minaeff and Wright,[6] Larvex consists essentially of sodium silico fluoride. Two of the brands of Eulan (Eulan Extra and W Extra) also are compounds containing fluorine, which element, presumably, is an intestinal poison.

Reference to the latter and other Eulan compounds may be found in the paper by Clark.[3] According to this writer, the application of fluorides and silicofluorides for mothproofing purposes was first claimed by the manufacturers of Eulan in their E.P.173,536.

(5) Experiments with Volatile Insecticides

Observations were made on the behaviour of the larvæ of *Tinea pellionella* in the presence of the vapour of three proprietary articles, namely "Flit," "Deleoil," and "Globol" (paradichlorbenzene) in closed atmospheres.

A small sample of 50's New Zealand fleece wool, light in grease (4·0% grease) and six larvæ were placed in each of two test tubes, one of which was open at both ends. The open ends were then loosely plugged with cotton wool and the tubes suspended horizontally, either in a large tin (18 litres capacity) or glass vessel (4 litres). A known amount of the insecticide, placed on a small pad of cotton, was then introduced into the chambers and the latter sealed and incubated. The contents of the tubes were subsequently examined with the results given in Table VI.

Table VI

Substance	Concentration	Period of Test	Observations	
			Tube open at One End	Tube open at Both Ends
Flit	0·5 c c per 18 l	33 days	All larvæ dead Wool slightly damaged	3 larvæ dead, 3 alive but abnormal Wool slightly damaged
	0·05 c c per 4 l	38 days	1 larva alive 4 metamorphosed alive Wool badly damaged	3 larvæ dead 1 pupated Wool slightly damaged
Deleoil	0 5 c c per 18 l	33 days	All larvæ dead Wool slightly damaged	All larvæ dead Wool slightly damaged
	0 05 c c per 4 l	38 days	1 larva alive remaining larvæ and pupæ dead Wool badly damaged	3 larvæ dead, 3 pupæ alive Wool fairly badly damaged
Globol	0 5 g per 18 l	33 days	All larvæ dead No action on wool	All larvæ dead No action on wool
	0 25 g per 18 l	38 days	All larvæ dead Wool probably undamaged	All larva dead Wool probably undamaged
	0 1 g per 18 l	31 days	All larvæ dead Wool probably undamaged	All larvæ dead Wool probably undamaged
	0·05 g (applied as a 5% sol in alcohol) per 18 l	28 days	All larvæ dead Wool probably undamaged	All larvæ dead Wool probably undamaged
	0 025 g per 18 l	23 days	5 larvæ dead 1 alive Wool not attacked	5 larvæ dead, 1 alive Wool very slightly attacked

The most striking result of these few tests is the superiority of Globol over the other insecticides, a concentration at the rate of only about half an ounce in 100 cub. ft of air space being required to give complete protection Even smaller concentrations were found to give satisfactory results but the participation of the alcohol in this connection was not ascertained.[3]

Globol, which has been repeatedly referred to in the literature[1,2,3] is a very volatile crystalline substance possessing a somewhat sweet smell and harmless to man The odour disappears somewhat slowly from woollen materials subsequent to storage Its removal, however, is facilitated by subjecting the goods to a current of hot air.

SUMMARY

Observations are described on the susceptibility of animal and vegetable fibres to damage by the larvæ of two species of clothes moth, *Tineola biselliella Hümmel* and *Tinea pellionella L.* under natural and controlled conditions.

The more important conclusions arrived at are as follows—

(1) Vegetable fibres and silk are not attacked by the above mentioned species of clothes moth.

(2) Certain animal fibres such as alpaca, camel hair, cashmere, and goat hair are highly susceptible to attack, particularly when in their natural state. The natural fleece of the sheep is also readily attacked but in the cases examined, the process of scouring enhanced further its susceptibility.

(3) Partially processed sheep's wools containing vegetable oil are not favoured by clothes moth larvæ, although such materials may not be considered to be immune from their activities.

(4) Fatty acids, applied in a concentration as high as 5·2% on the weight of wool, do not produce complete immunity. In this respect, these substances are inferior to certain mineral oils examined.

(5) Worsted cloth impregnated with solutions of "Larvex" and "Eulans" are satisfactorily proofed against the action of clothes moths. Infected wool stored in a closed atmosphere containing paradichlorbenzene is also efficiently protected.

The writers' thanks are due to Mr. J. Stott who has very ably assisted with this work.

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10—APPARATUS FOR THE MEASUREMENT OF FLOW AND RELAXATION OF TEXTILE FILAMENTS

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SUMMARY

This paper describes an improved model of the Polanyi tester which may be used for measuring the rate of flow of single filaments of rayon under constant loads at various temperatures and in various atmospheres or liquid mediums. It further describes an apparatus which was developed from the suggestions of E. Schmid in order to make possible the measurement of the relaxation of rayon filaments at constant small extensions. This apparatus is also more suitable than the Polanyi for the accurate measurement of flow under small loads.

POLANYI TESTER AS ARRANGED FOR FLOW TESTS

In connection with an investigation of the elastic after-effect phenomena of rayon and other filaments reported in a second paper, the problem arose of developing suitable apparatus and procedure for the measurement of flow, i.e., rate of change of length of a filament under constant load; and of relaxation, i.e., rate of change of the load supported by a stretched filament held at a constant length.

Of the several types of existing apparatus, such as those of Krais,[1] Leis[2] or Polanyi,[3] adaptable to the measurement of flow of filaments, the latter was used for the first experiments. The improved model of the Polanyi tester which was adapted to this work is illustrated in Fig. 1.

The apparatus consists in principle of a micrometer screw (*c*) which carries the lower clamp (*b*) and a flat steel beam, or spring (*f*), supported on two knife edges, from the middle of which the upper specimen clamp (*a*) is hung by means of a suitable wire hook (*g*). By lowering the micrometer screw by means of a suitable worm and wheel arrangement (*d*) the resulting stress in the mounted specimen is transmitted to the spring which is consequently deflected. An exact measurement of this deflection, which is made by means of two small mirrors mounted on the ends of the spring in conjunction with the telescope and scale arrangement of Poggendorf, provides directly a measure of the load on the specimen. The magnitude of the extension is given by the difference between the vertical movement of the micrometer screw and the deflection of the spring. Simultaneous readings of the position of the micrometer screw and the deflection of the spring (scale reading) provide points from which the stress-strain curve can be constructed. Fig. 2 and 3 show examples of stress-strain curves obtained on single filaments of Bemberg (cuprammonium) and Lilienfeld (greatly stretched viscose) rayons in air at several relative humidities, by means of this apparatus.

Procedure for Flow Measurements

In order to measure the flow by means of the Polanyi apparatus the mounted filament is first deformed by a definite load, by turning the wheel which drives the micrometer screw downward as rapidly as possible by hand to the desired point. Then, in order to hold this load constant for the remainder of the experiment, the micrometer screw must be lowered still further (but at a very much slower rate, which is determined by continuous observation of the scale reading in the telescope which must be held constant by suitable motion of the micrometer screw) as otherwise the flow of the specimen would cause a diminution of the load upon it. The position of the calibrated

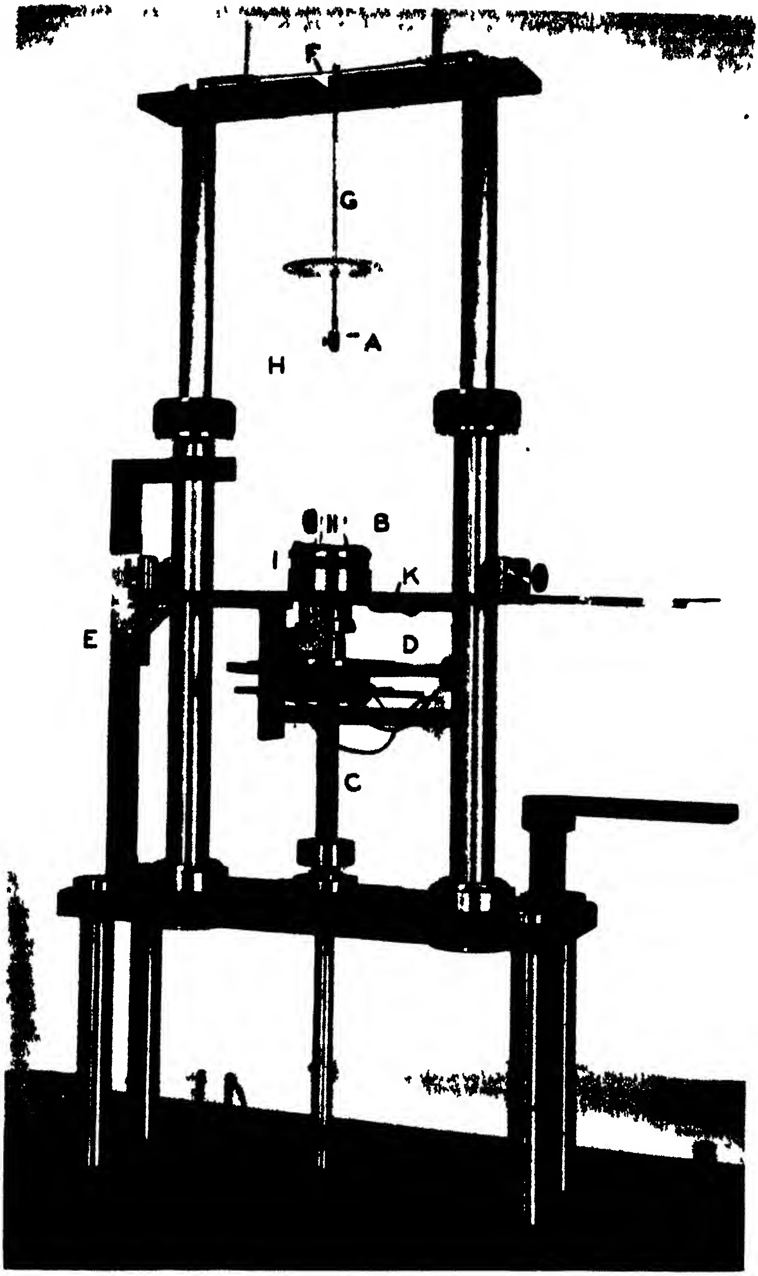


FIG. 1 Polanyi Tester

- A Upper Clamp
- B Lower Clamp
- C Micrometer Screw
- D Calibrated Wheel
- E Side Scale for indicating full revolution of wheel
- F Steel Spring with mounted mirrors
- G Wire Hook connecting clamp and spring
- H Glass Mantle
- I Brass Receptacle for mantle
- K Inlet Tube for prepared atmosphere

wheel at various times gives the data for the flow curve, which represents the extension under a constant load as a function of the time.

The pitch of the micrometer screw is 0·5 mm. per revolution and the calibrated wheel is divided into 180 parts. One wheel division therefore =1/360 millimeter movement of the lower clamp (*b*).

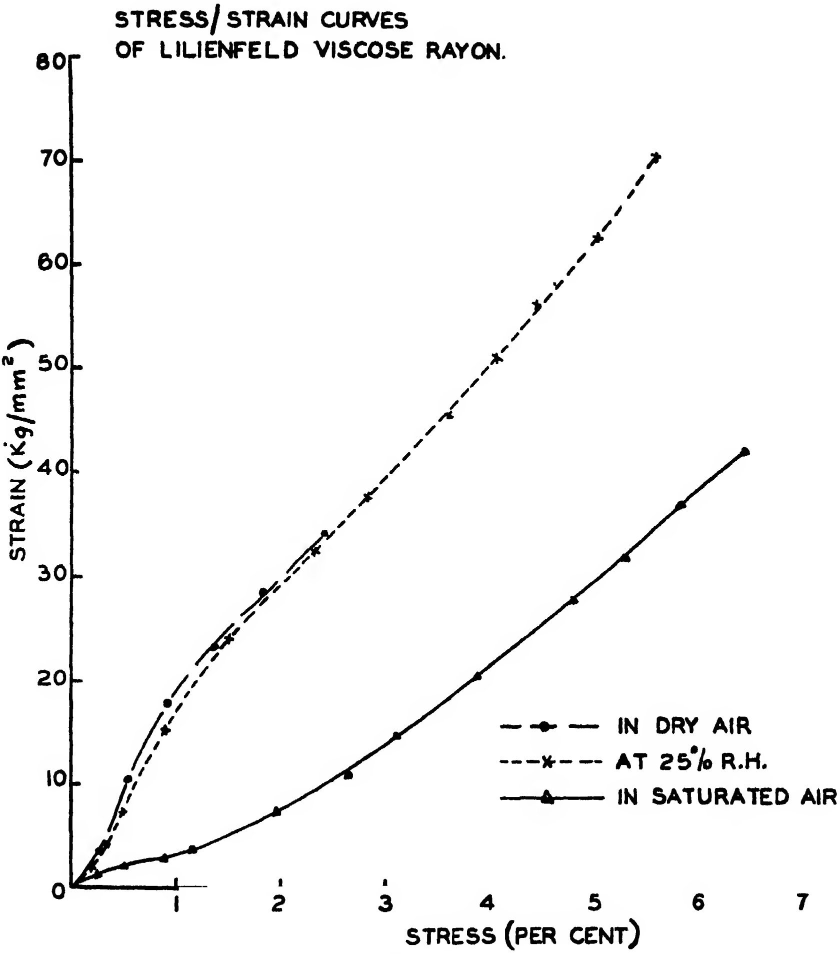


Fig. 2

Some load fluctuation is inevitable since the calibrated wheel can only be turned farther after the flow of the specimen has caused an actual change in length and load sufficient to be perceptible in the telescope reading. On the improved Polanyi apparatus this fluctuation was reduced by increasing the sensitivity of the beam about five-fold as shown in Table I. This reduced the fluctuations in scale readings to ±0·02 cm.=3 mgm. maximum load fluctuation. Even this small fluctuation amounts to from 0·1% to 1% of the loads applied in the experiments.

Table I

Spring	Spring Dimensions (mm)	Deflection (mm per gm)	Deflection Constant (mm per cm scale reading)	Load Constant (gm per cm. scale reading)
"B" (small Polanyi app)	40 × 0·99 × 0·19	0·137	0·16	0·019
"E" (new Polanyi app)	120 × 1·50 × 0 30	0·70	0·047	0·068

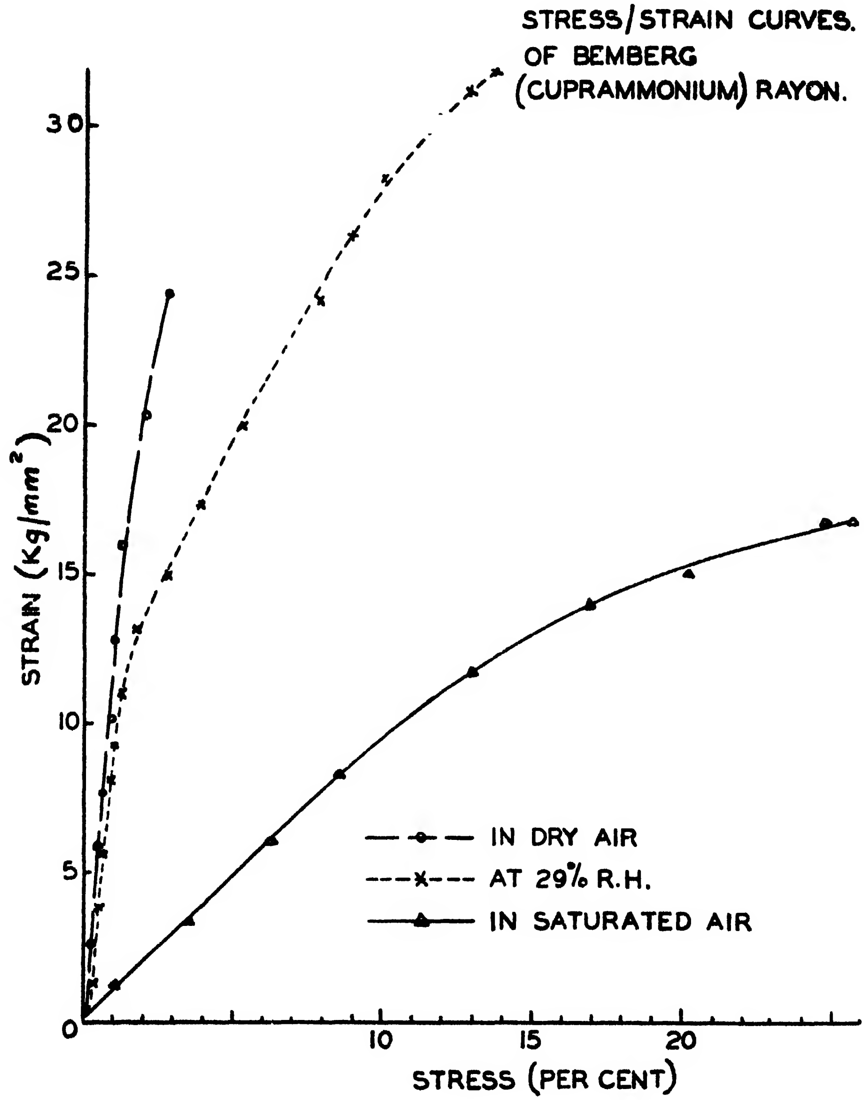


Fig 3

The calibration experiments revealed a slight deviation from strict proportionality between load and deflection which was caused by the moments of the mirrors as their inclination from the vertical increased. However, this deviation was so small in comparison to the influence of differences in cross sectional area of the filaments on the stress determination that the mean

value was amply exact for the calculation of the load. This deviation is without any influence whatever on the course of the flow curve itself.

To one end of the steel spring is soldered a small brass block with a groove in it which rests on one knife edge. The other end of the spring glides on its knife edge as the spring deflects. The friction between spring and knife edge, which interferes with the proportionality between the stress in the specimen and the scale reading and causes an uncertainty in the loading, adds to the fluctuation mentioned above. It was greatly reduced by securing to the under side of the spring at the movable end a small plane glass plate with rounded edges. This reduced the "hysteresis" (difference between scale readings obtained by approaching a given load from a smaller load and from a greater load) from about 0·2 cm. to about 0·03 cm. scale reading. The danger of premature termination of an experiment, due to an external vibration suddenly releasing the frictional resistance of the spring, thus causing a small jump in the scale reading, remained.

The use of the longer spring made the system composed of stressed filament, spring and mirrors, much less sensitive to external shocks which tend to throw it into elastic oscillation. Even with the long spring, however, and special casein cushions under table legs and apparatus which was set up in a vibration free room (with separate foundation), it was necessary to conduct experiments after other machines in the building had been shut down.

The first experiments revealed that the rate of loading attainable by hand operation of the wheel was far too slow. By drawing on a long cord which was wrapped about the drum on which the wheel was mounted, the rate of loading was greatly accelerated. In order to bring a scale division exactly in line with the cross-hair in the telescope (which is necessary in order to permit the exact observation of very slight movements of scale relative to cross-hair) it was necessary to finish the loading operation by hand. It was, therefore, impossible to maintain the same rate of loading in different experiments. The greater the number of turns necessary to reach the desired load—whether because the chosen load itself was greater or because of the physical state of the filament (swelling)—the longer was the loading time and the greater the influence of the above-mentioned uncertainties.

Control of Atmospheric and Temperature Conditions

In order to control the atmosphere surrounding the specimen, the latter is tested within the glass mantle (*h*, Fig. 1) whose upper end is ground off plane. This mantle with its ground glass cover isolates the fibre completely from the atmosphere of the room, since the prepared air which enters the mantle at the bottom by means of the inlet tube (*k*) escapes through the small hole in the glass cover at sufficient velocity to prevent any counter diffusion inward.

By closing the inlet tube (*k*) the mantle may be filled with water or other liquid thus immersing the filament completely during an experiment.

Production of Dry Air

For the experiments made in dry air, air from a compressed air flask was passed through a chain of wash bottles containing calcium chloride, concentrated sulphuric acid and phosphorus pentoxide, all connections being glass tubing held end to end by rubber vacuum tubing sealed over with pitch. A test showed that at a rate of flow of 4 litres per hour the moisture absorbed by

a U tube filled with phosphorus pentoxide and protected at its outer end by a second phosphorus pentoxide filled tube amounted to 0·3 mgms. which corresponds to a relative humidity of 0·04%.

This rate of flow of 4 litres per hour results in a linear velocity of flow of 16 cm per second through the exit hole in the glass cover disc.

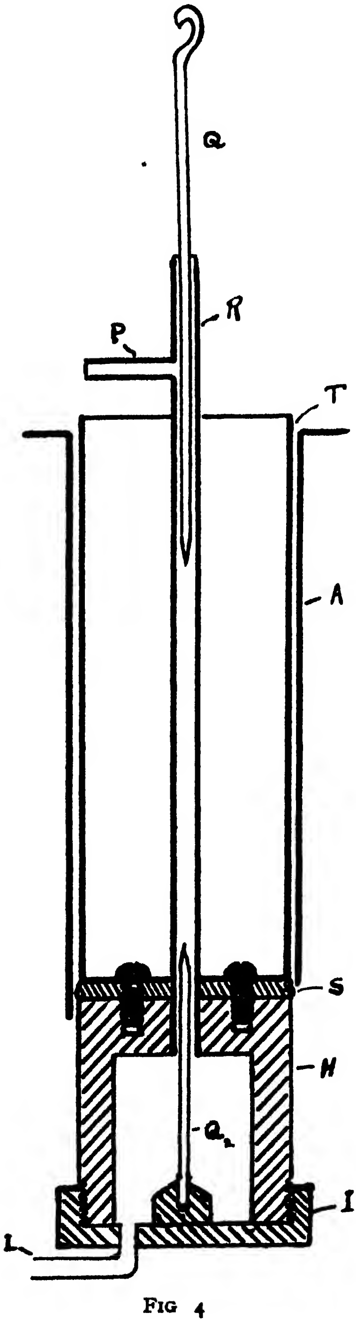
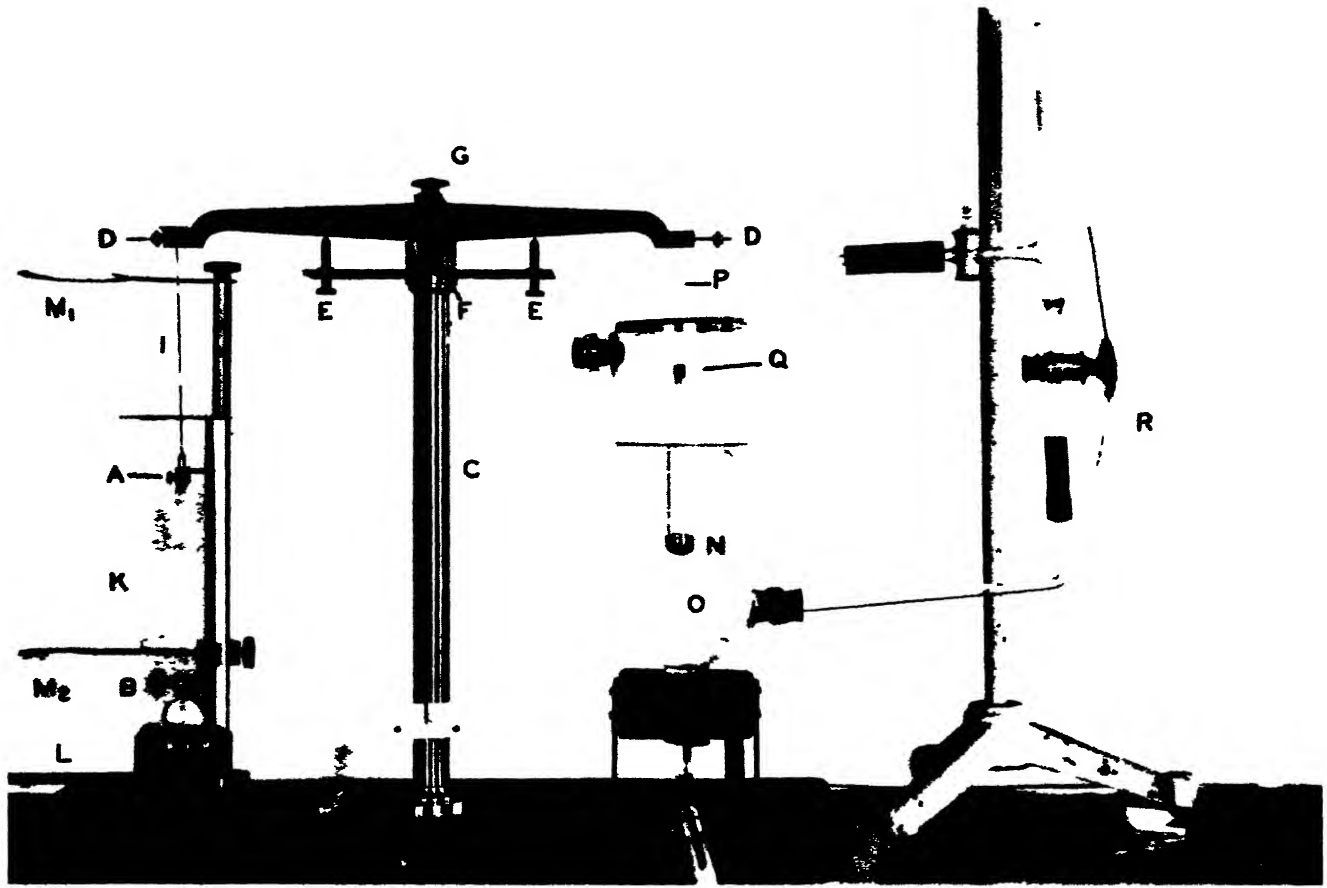


FIG 4

A calculation of the rate of diffusion of water vapour from the room inward through the hole in the glass cover of the mantle, based on the diffusion equation of Fick and assuming the maximum concentration differential (i.e. saturated air outside and absolutely dry air inside), gives a linear rate of diffusion inward of 1·14 cm. per second. The rate of air flow of 4 litres per hour, therefore, is ample to prevent diffusion of moisture into the space within the mantle during an experiment.

For the experiments at temperatures other than room temperatures the glass mantle was replaced by a thermal jacket, a cross section of which is depicted in Fig. 4. The fibre is mounted within the tube R (by means of pitch for low temperatures or glue for higher temperatures) between the pointed quartz rods (Q and Q) which replace the usual clamps. The cup (T) surrounding (R) is filled with the warming or cooling medium. For low temperatures the cup was filled with an ether—solid carbon dioxide mixture or with liquid air. For temperatures above that of the room it was filled with mineral oil which was heated by a suitably controlled electrical resistance coil. The outer sleeve guide was wrapped with thick felt insulation. In using the thermal jacket for experiments at higher or lower temperatures, the specimen was first thoroughly dried in the usual manner by passing the dry air in at (1) and up through the tube (R) for a long time. Before pouring the cooling or warming agent into the cup (T) however, the stopcock on the air supply was closed and the air stream switched to the side tube (P) so that the air surrounding the specimen was quiet. This procedure made possible a more certain cooling or warming of the air and specimen within (R) and at the same time the continued dry air stream from (R) protected the specimen from the moisture which would otherwise have reached it by diffusion from the outside air.


G
D
D
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M1
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F
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Q
R
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C
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O
M2
B
L

APPARATUS FOR MEASURING RELAXATION AND FLOW

In order to measure relaxation phenomena an apparatus which was designed primarily for this purpose but which also offers advantages over the Polanyi apparatus for flow measurements was developed from a design suggested by E. Schmid. It combines a balance beam and an optical lever with a float-like loading arrangement similar to that of the improved O'Neill Tester used by Mann and Peirce.[4] This combination makes possible the accurate determination of very small changes in length of the test specimen as well as in load and provides a control of both which permits the accurate observation of flow and relaxation phenomena under controlled atmospheric conditions. In the form developed, loads of a few grams may be applied and load changes of a few milligrams and length changes of a few tenths of a millimeter may be measured.

The apparatus (Fig. 5) consists of a balance beam (*dd*) whose position may be read by means of the customary pointer and more accurately by means of a mirror (*g*) mounted on it, a distant scale and a telescope (not shown). The filament to be tested is mounted vertically between clamp (*a*) suspended by the wire (*i*) from the left end of the beam and clamp (*b*) which is fixed to the baseboard. The mounted filament is separated from the outer atmosphere by a mantle and cover (*k*) similar to that of the Polanyi apparatus. The adjustable U-shaped supports (*m*) and (m_2) serve to support the mantle and its cover glass while the specimen is being mounted.

Loading Arrangement for Relaxation Experiments—The problem of investigating relaxation requires that the load on the filament be alterable in such a way as to keep the beam stationary. To accomplish this the weight is in the form of a float (*n*) of uniform cross section having a hook (*q*) which can engage the hook (*p*) hanging from the right end of the beam. The float hangs or floats vertically within a reservoir (*o*).

The liquid level in the reservoir, and hence the load, can be quantitatively controlled at will by allowing liquid to flow into the reservoir from burette (*r*) or out through the stopcock on (*v*) into a tared vessel on a balance.

A filament under a constant load will increase in length (flow); if the load is removed it will tend to contract. By gradually and suitably decreasing the load on a filament which has been extended to a certain length the length may be held constant. This is accomplished by first running liquid rapidly out of the reservoir to load and extend the filament to the desired length and then by running liquid into the reservoir at such a rate as to hold constant the scale reading of the telescope and hence the balance beam and the filament length. From readings of the amount of liquid allowed to flow out of or into the reservoir and of the time, the relaxation curve may be constructed.

Loading Arrangement for Flow Experiments—The same apparatus with a change in the loading mechanism is suitable for flow experiments in which the total changes in length are small. For this purpose a hanging weight fastened to hook (*p*) by a fine supple filament of silk provides the constant load. In place of the float a free-floating glass dish is placed on the surface of the reservoir on which the weight rests at the start of the experiment. By lowering or raising the level of the liquid, so that the floating dish releases or supports the hanging weight, loading or unloading may be rapidly accomplished.

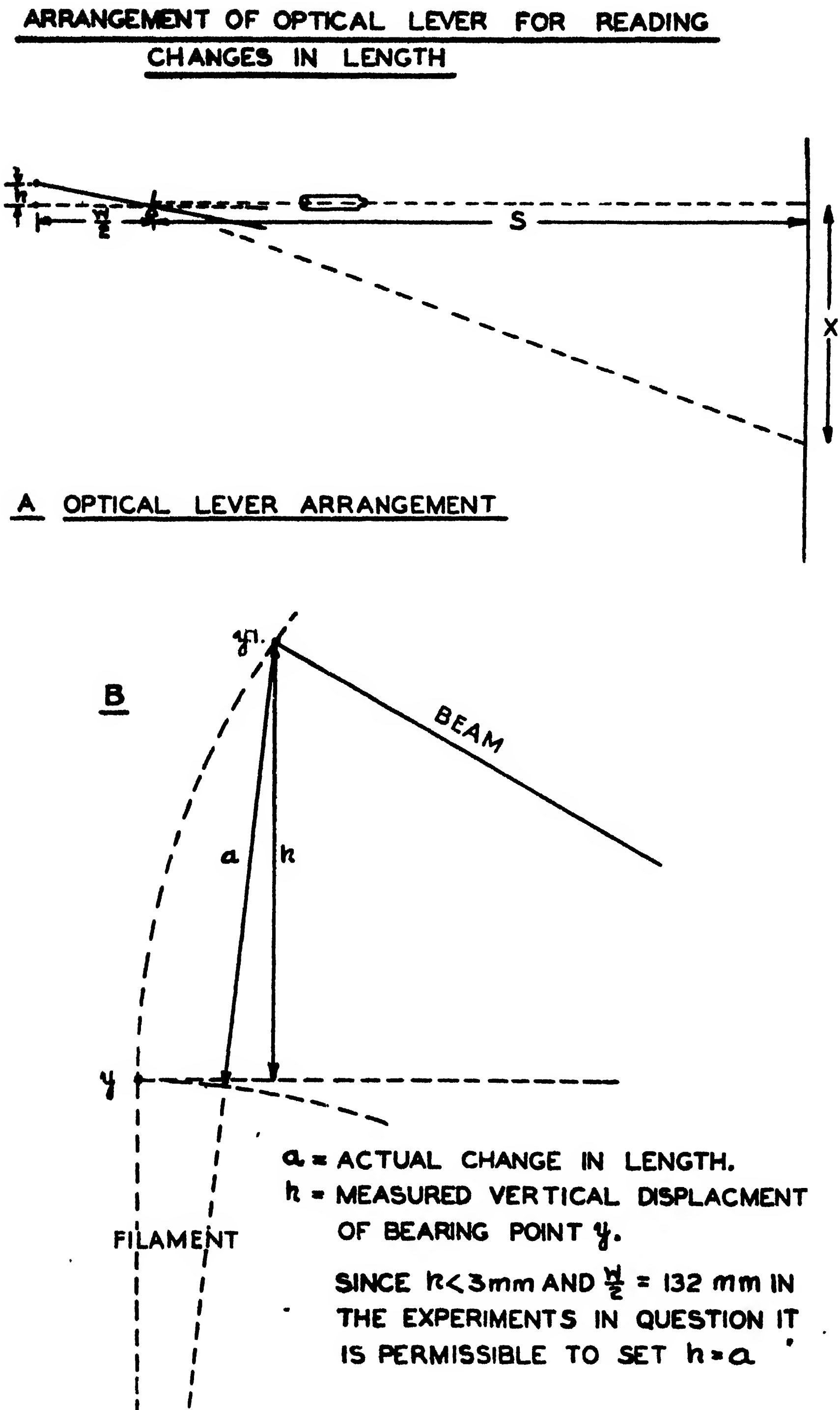
ARRANGEMENT OF OPTICAL LEVER FOR READING CHANGES IN LENGTH
h
W/2
S
X
A OPTICAL LEVER ARRANGEMENT
B
y1.
BEAM
a
h
y
FILAMENT
a = ACTUAL CHANGE IN LENGTH.
h = MEASURED VERTICAL DISPLACMENT OF BEARING POINT y.
SINCE h<3mm AND W/2 = 132 mm IN THE EXPERIMENTS IN QUESTION IT IS PERMISSIBLE TO SET h=a

Fig. 6

The smoothness of loading is affected somewhat by oscillations set up by the swinging weight which prevent an immediate reading of the beam position. Careful centring of the weight beneath the hook at the start reduces this trouble to some extent. In order to further damp the oscillations the dish was filled with mineral oil to such a depth that the weight remained submerged in it during a whole experiment. A correction for the buoyant effect of the oil is of course necessary.

Length of Specimen

This may be varied by using hooks at (*i*) of different lengths. In the majority of experiments the distance between the clamps (when the balance was in equilibrium in the zero position) was 145·0 mm.

Measurement of Changes in Length of Specimen

Referring to the sketch of the optical lever arrangement in Fig. 6, the vertical component (*h*) of the displacement of the left bearing point (*i*) of the beam is—

$$h = \frac{\frac{w}{2} \cdot \chi}{\sqrt{\chi^2 + s^2} + s} \qquad (1)$$

Since χ is small compared with s, the equation may be simplified to—

$$h = \frac{w\chi}{4s} \qquad (2)$$

Application of this expression to the present apparatus, in which $w=$ 265·4 mm. and $s=6100$ mm., yields $h=0{\cdot}108$ mm. per cm. scale reading.

The maximum vertical displacement of the point (*i*) during the experiments was $h=3$ mm with a specimen of about 145 mm. length. For this small displacement the changes in length (*a*) of the fibre may be considered equal to the vertical component (*h*). (Fig. 6B)

Sensitivity

The sensitivity, which was made as great as possible, amounted to 2·5 cm. change in scale reading, or $0{\cdot}1^{\circ}$ movement of the beam about its fulcrum per milligram change in load.

Measurement of Load Changes with Float Arrangement

The whole float weighs 3·66 gms. in air, but because of its rounded bottom and the disturbance due to surface tension effects which would be caused by the emergence of this portion from the liquid, its limit of useful load is about 3·5 gms.

When the balance is loaded, every increase in the quantity of liquid in the reservoir raises the float which hangs on the right end of the beam, and hence alters the position of the beam. In order to counteract this a weight P_1 must be removed from the left side. For a cylindrical float and cylindrical reservoir the relationship between loads and volumes is—

$$P_1 - P_2 = \frac{s.d^2}{D^2-d^2}\,(V_2 - V_1) \qquad (3)$$

in which
P = load in grams.
V = volume of liquid in the reservoir.
s = specific gravity of the liquid.
d = outside diameter of float.
D = inside diameter of reservoir.

The signs P_1, P_2, and V_1, V_2, refer to two conditions in which the balance is in equilibrium in the same position.

The absolute value of the load P_2 is obtained from the expression by making $P_1 = 0$. The corresponding V_1 refers then to that quantity of liquid by which the float floats free with the hooks (p) and (q) just in contact with one another. For the apparatus as described—

$$d = 0{\cdot}957 \text{ cm.}$$
$$D = 6{\cdot}80 \text{ cm.}$$

For the use of n-propyl alcohol specific gravity $s = 0{\cdot}804$, the constant in equation (3) is—

$$k = \frac{s\,d^2}{D^2 - d^2} = 0{\cdot}01624 \text{ grams load per c.c. liquid.}$$

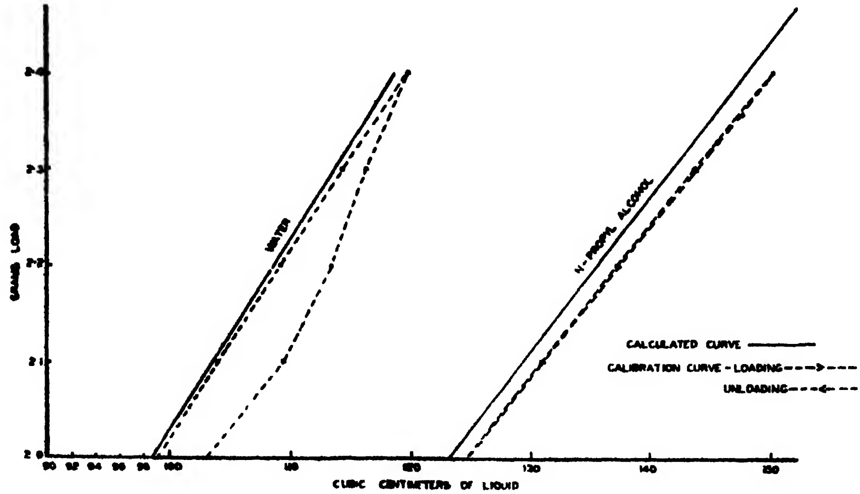

FIG 7

In order to determine the zero point from which to measure changes in V, the liquid level is lowered gradually from a level at which the float floats quite freely until the first motion of the scale is observed in the telescope. Since 0·2 mm. scale movement (corresponding to 0·08 mgm.) is easily observable, the zero point is determinable with the same degree of accuracy as the determination of changes in load.

For the useful range of load equation (3) was experimentally tested by calibration experiments on the apparatus, by loading and unloading the left end of the beam step by step with known weights. At every step the liquid level was so adjusted that the beam stood again in the zero position.

In Tables II and III, and IIIa, the loads are recorded in the first column in the same order in which they were applied in the experiment. The second column gives the difference between the volumes of liquid in the reservoir at zero load and at the load P. The volume difference, as calculated by equation (3), is given in column 3, and the difference between calculated

and measured volume in column 4. The results of Tables II and III, and IIIa, are given diagrammatically in Fig. 7 and in Fig. 8, which reproduces the portion between 2·0 and 2·4 gms. load to a larger scale in order to make more clear the behaviour discussed in the next paragraph.

The first calibration using water revealed that the deviations from the calculated value are irregular and that the observed values for a sinking liquid surface differ from those for a rising surface. This deviation from the expected proportionality, which is very evident in Figs. 7 and 8 is greatest at the turning point where a rising surface follows immediately upon a sinking one, and is apparently due to a change in the form of the meniscus of the liquid surface.

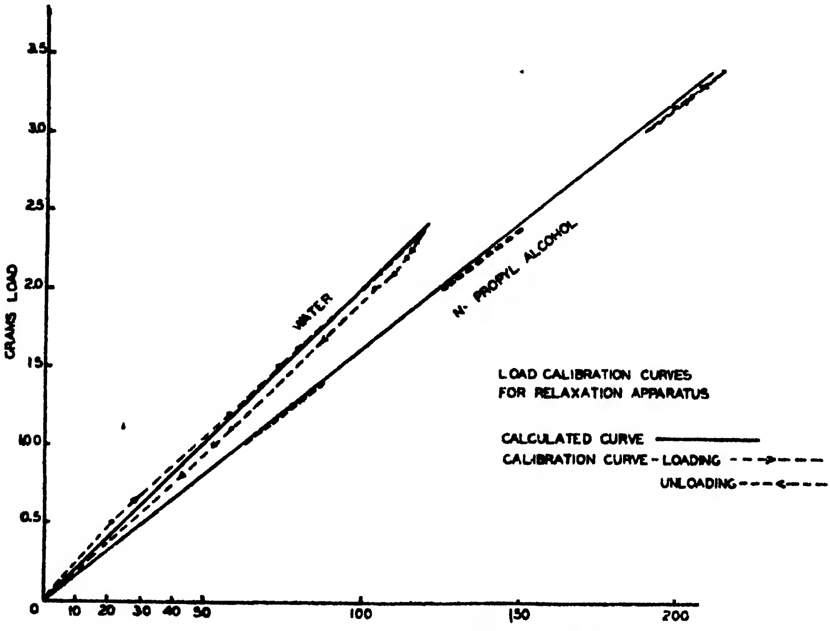

FIG 8

A second calibration was, therefore, made, using instead of water normal propyl alcohol. As shown in Figs 7 and 8, the use of propyl alcohol resulted in a much more uniform proportionality, and greatly reduced the irregularity at the turning points and the spread between increasing and decreasing load values. There is, however, a nearly constant difference of about 1·3–1·7% between the calculated and the observed values which can only be due to slight inaccuracy in the values of the D, *d*, or *s* in equation (3).

The calibration shows that it required a mean of 50·43 grams, or 62·72 c.c. of normal propyl alcohol to effect a change in load of 1·000 gram, and that $k = 0{\cdot}01594$ for loading, and 0·01596 for unloading. All relaxation experiments were evaluated by the use of equation (3), substituting the actual value of $k = {\cdot}01594$ for its theoretical value.

Correction Necessary because of Altered Position of the Balance Beam

If the unloaded beam moves "x" scale divisions (in the telescope) from its zero position during loading, then in equation (3) V_1^{x} should be substituted for V_1.

V_1^{x} is the volume at which the float is just in contact with the beam for the position of x cm. scale reading of the latter. V_1° on the other hand is the volume at which the float and beam are just in contact for the zero position of the beam. Since $V_2 - V_1^{\circ}$ is actually determined during an experiment, $V_1^{x} - V_1^{\circ}$ must be determined as a correction. The volume—

$$V_1^{x} - V_1^{\circ} = (D^2 - d^2)\frac{\pi h}{4} = (D^2 - d^2)\pi\,\frac{wx}{16s} \tag{4}$$

from which for $x = 1$, $V_1^{1} - V_1^{\circ} = 0{\cdot}4$ c.c.
Hence from the total amount of liquid run out of (o) an amount $= 0{\cdot}4$ cc. x scale reading must be subtracted.

Evaporation of Alcohol during Experiment

The reservoir is closed at the top by a cork having a small hole in its centre for the free movement of the wire (*q*). In order to prevent change in liquid level, due to evaporation, this opening was further reduced as far as practicable by laying two cover slips on the cork. A special experiment showed that in 4½ hours the float pulled down the unloaded beam by an amount corresponding to 0·11 cm. scale movement because of evaporation. This rate of evaporation is so slow that its effect on the experiments was negligible.

Table II
Load Calibration of the Relaxation Apparatus

Liquid—Water.

Calibrating Weight P. (g.)	Observed Volume Difference V_2-V_1 (cm.^{3})	Calculated Volume Difference V_2-V_1 (from equation) (cm.^{3})	Deviation of Observed from Calculated Value of V_2-V_1 (cm.^{3})
Loading—			
0	0	0	
0·50	21·03	24·68	−3·65
1·20	58·13	59·23	−1·10
1·50	73·36	74·03	−0·67
2·00	99·22	98·72	+0·50
2·10	104·17	103·65	+0·52
2·20	109·27	108·59	+0·68
2·30	114·32	113·53	+0·79
2·40	119·67	118·46	+1·21
Unloading—			
2·30	116·21	113·53	+2·68
2·20	113·85	108·59	+4·86
2·10	109·57	103·65	+5·92
2·00	103·22	98·72	+4·50
1·00	53·47	49·36	+4·11
0	0·47	0	+0·47

Table IIIa
Load Calibration of the Relaxation Apparatus

Liquid—Normal Propyl Alcohol

Calibrating Weight P. (g.)	Observed Volume Difference V_2-V_1 (cm.^{3})	Calculated Volume Difference V_2-V_1 (from equation) (cm.^{3})	Deviation of Observed from Calculated Value of V_2-V_1 (cm.^{3})
Unloading—			
1·10	0	0	0
1·08	1·31	1·231	0·08
1·06	2·58	2·463	0·12
1·04	3·83	3·694	0·14
1·02	5·10	4·926	0·18
1·00	6·36	6·158	0·21
Unloading—			
2·10	0	0	0
2·08	1·37	1·231	0·14
2·06	2·68	2·463	0·22
2·04	3·95	3·694	0·26
2·02	5·21	4·926	0·29
2·00	6·47	6·158	0·31
Unloading—			
3·10	0	0	0
3·08	1·41	1·231	0·18
3·06	2·69	2·463	0·23
3·04	4·06	3·694	0·37
3·02	5·34	4·926	0·42
3·00	6·60	6·158	0·44

Table III
Load Calibration of the Relaxation Apparatus

Liquid—Normal Propyl Alcohol (sp. gr. = 0·804)

Calibrating Weight P. (g.)	Observed Volume Difference V_2-V_1 (cm.^{3})	Calculated Volume Difference V_2-V_1 (from equation) (cm.^{3})	Deviation of Observed from Calculated Value of V_2-V_1 (cm.^{3})
Loading—			
0	0	0	0
1·0	62·36	61·58	+0·78
1·1	68·62	67·73	+0·89
1·2	74·82	73·89	+0·93
1·3	81·03	80·05	0·98
1·4	87·31	86·21	+1·10
Unloading—			
1·3	80·89	80·05	+0·84
1·2	74·65	73·89	+0·76
1·1	68·38	67·73	+0·65
1·0	62·17	61·58	+0·59
0	−0·23	0	−0·23
Loading—			
0	0	0	0
2·0	124·8	123·15	+1·65
2·1	131·0	129·31	+1·69
2·2	137·3	135·47	+1·83
2·3	143·7	141·63	+2·07
2·4	150·0	147·78	+2·22
Unloading—			
2·3	143·48	141·63	+1·85
2·2	137·19	135·67	+1·72
2·1	130·9	129·31	+1·59
2·0	124·64	123·15	+1·49
0	−0·84	0	−0·84
Loading—			
0	0	0	0
3·0	188·0	184·73	+3·27
3·1	194·3	191·88	+2·42
3·2	200·7	197·04	+3·66
3·3	206·9	203·20	+3·70
3·4	213·1	209·36	+3·74
Unloading—			
3·3	206·56	203·20	+3·36
3·2	201·32	197·04	+4·28
3·1	194·0	191·88	+2·12
3·0	187·72	184·73	+2·99
0	−0·92	0	−0·92

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11—THE FLOW AND RELAXATION OF RAYON FILAMENTS

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SUMMARY

(1) This paper deals with the experimental investigation of rayon filaments with respect to mechanical deformations included under the general term "elastic after-effect."

(2) The rate of flow of rayon filaments under constant load and its relation to the temperature and to the degree of water absorption has been measured.

(3) Filaments of viscose rayon were subjected to a pretreatment consisting of swelling in water and drying in air at a very small tension in order to remove bends and kinks and to equalise the internal stresses in the filament.

(4) Flow and relaxation curves for viscose rayon filaments were obtained by means of an apparatus developed especially for the purpose from the suggestion of E. Schmid.

(5) The course of the relaxation curve is approximately the same at various loads, i.e., the relative rate of relaxation is independent of the load and therefore of the cross section. This result agrees with Boltzmann's theory of after-effect. The flow curves deviate from the Boltzmann theory in that the relative rate of flow is markedly dependent upon the load (apparently because of an alteration in the inner structure due to flow). The relationship between the flow curve and recovery curve of each individual filament is in agreement with the Boltzmann theory. The after-effect behaviour of rayon up to the point where deviations, due to alteration of the inner structure, probably occur—is therefore explained by the Boltzmann theory.

(6) The rate of flow increases rapidly with increasing temperature. The rate of flow is some thirty to fifty times as great for the wet material as for the dry. The distribution of the plastic inhomogeneity in the rayon structure (to whose presence the after-effects are ascribed) is apparently unaffected by changes in temperature and in the degree of water absorption.

INTRODUCTION

Theories on Elastic After-effect Phenomena

Maxwell[1] discussed the case of an ideal substance in which the deforming force, the deformation, and the rate of deformation are in unequivocal relationship to one another. He makes the statement—

$$\frac{dk}{dt} = E\frac{dl}{dt} - \frac{k}{\tau} \tag{1}$$

in which t = time.

k = deforming force.

l = deformation.

E = constant—the modulus of elasticity for the type of deformation in question.

τ = constant—called the "time of relaxation."

For $\tau = \infty$, equation (1) becomes Hooke's law: $k = E{\cdot}l$.

Integration of equation (1) for constant deformation (l = constant) gives the equation of the "relaxation curve."

$$k = k_o \cdot e^{-\frac{t}{\tau}} \tag{2}$$

According to this equation, the tension in a deformed body under a constant deformation decreases exponentially; after the time τ it has dropped to the e^{th} part of the initial tension.

Integration of equation (1) under constant tension (k = constant) gives the equation of the "flow curve"—

$$l = l_0 + \frac{k}{E\tau} \cdot t \tag{3}$$

This equation indicates that under constant load the deformation proceeds at a constant rate which is proportional to the load.

The experimental testing of Maxwell's relaxation equation by means of the torsional elasticity of glass filaments and silver wire was undertaken by F. Kohlrausch,[2] whose results did not agree with the theory. Wiechert,[3] therefore, expressed the supposition that the actual non-exponential relaxation curve was to be explained by the superposition of a number of relaxation processes on one another, each of which followed the exponential law. The significance of this assumption will be discussed later.

The second consequence of the Maxwell theory, namely, the constant rate of flow under constant load, has also failed of confirmation in experiments on filaments, wires, etc. It has been sought to identify the proportionality factor $\frac{1}{E\tau}$ which occurs in equation (3) with Poiseuille's coefficient of friction for fluids, for in the case of ordinary fluids a constant rate of flow under constant pressure is actually observed. It appears, however, that the analogy is a purely formal one which has no simple physical significance.

The real substances so far investigated differ from the simple behaviour of an ideal elastic substance by reason of the appearance of elastic after-effects which manifest themselves as follows—The deformed body does not return instantly to its original form after the cessation of the action of the deforming force, but reaches it by means of a slow recovery from the originally imparted deformation. Boltzmann[4] explained this phenomena by means of the assumption that the stress acting in a body at the time t is determined not only by the deformation at the same time t, but also by the previous deformations z where z is the past time and can have values between $-\infty$ and t. Boltzmann used the "after-effect function" $\varphi(t - z)$ in order to state the contribution, which is made by the deformations which have occurred in the past, to the deformation caused by the force acting at the time t. The function $\varphi(t - z)$ represents the "recollective capacity" of the body for past deformations.

For *flow* in the time between 0 and $+t_1$ under the constant force k, Boltzmann derives the equation—

$$l(t) = \frac{F}{E} k \left[1 + \beta \int_0^{t_1} \varphi(t_1 - z) dz \right] \tag{4}$$

in which F = a geometrically calculable form factor.

β = an empirical constant.

For the *recovery* in the time from t_1 to t, he obtains the equation—

$$l(t) = \frac{F}{E} k\beta \left[\int_0^{t+t_1} \varphi(t + t_1 - z) dz - \int_0^{t} \varphi(t - z) dz \right] \tag{5}$$

For *relaxation* one obtains from the Boltzmann theory the equation—

$$k(t) = \frac{E}{F} l \left[1 - \beta \int_0^{t} \varphi(t - z) dz \right] \tag{6}$$

A comparison of equations (4) and (6) shows that the flow and relaxation curves must have the same form according to Boltzmann's theory.

The integral in these three equations gives the sum of the effect of all past deformations. For longitudinal deformations $\frac{E}{F} = \varepsilon$, the modulus of elasticity (Young's Modulus).

Of the deductions which serve to test the Boltzmann theory, the following two lend themselves to experimental investigation. (Becker[5] gives further possibilities of testing the Boltzmann theory.)

In a series of flow and recovery experiments under different loads, the rate of flow at the same time t should be proportional to the acting force (load), and the rate of recovery should be proportional to the deformation.

Secondly, the after-effect functions calculated from the flow curve and from the relaxation curve should be identical.

Boltzmann's theory has been confirmed on glass filaments and polycrystalline metal wires.[3] In these experiments it was found that for $t > 1$ the after-effect function $\varphi(t - z)$ could be approximately represented by $\frac{1}{t - z}$ and $\int_0^t \varphi(t - z)dz$ by $ln\, t$.

Single crystals behave quite differently from the amorphous and polycrystalline substances. Knowledge of their mechanical deformations has been essentially advanced by the experimental investigation of single metallic crystals. It has been shown that the plastic deformation proceeds by means of slippage along crystallographically definable slip planes. The same mechan sm of deformation must be assumed for the single kernels in a polycrystalline metal.

Von Wartenburg[6] found no elastic after-effect in the case of single crystals. Even when the deformation is so great that the metal is permanently deformed the new condition is very quickly reached. Von Wartenburg concluded, as a result of this observation, that the after-effect is caused by a "plastic inhomogeneity" such as that which occurs at the kernel boundaries of polycrystalline bodies and at the phase boundaries of polyphase amorphous bodies. After-effect is therefore impossible in a single phase homogeneous amorphous system.

Following the investigations of Von Wartenburg, which developed for the first time a physical-chemical viewpoint in connection with the phenomena of resistance to deformation, R. Becker[5] developed the theory farther in the same direction. He endeavoured to establish a connection between part plastic, part elastic deformation and variations in thermal activity and, in the case of amorphous bodies, the resulting molecular exchange of places. In crystals the breakdown of elasticity is supposed to be caused by variations which affect a greater number of atoms simultaneously.

In a second paper[7] Becker develops mathematically the Von Wartenburg thought on plastic inhomogeneity in order to explain the elastic after-effect. In amorphous substances Maxwell's equation (1) is assumed to hold for the small homogeneous particles. On the assumption that the relaxation time is comparable to the average period of rest of a molecule in a position of equilibrium (i.e. that the one can be set down as proportional to the other

with a proportionality factor which is not far from one), he arrives at a relation between the diffusion constant (D), the viscosity (η), the modulus of shear (G), and the mean distance between molecules or molecular diameter (δ) in the form—

$$D\eta = \frac{a\, G\, \delta^2}{6}$$

For a plastic inhomogeneous material he arrives at the Boltzmann theory. The course of the relaxation curve is to be considered according to a generalisation of Weichert's suggestion as the super position of a series of exponential curves. According to Becker, the Maxwell theory is not even applicable to the homogeneous particles in crystalline substances and corresponding deviations from the Boltzmann theory are therefore to be expected.

According to Becker also the quantitative calculation of the after-effect function is dependent upon a knowledge of the distribution of the different degrees of plasticity among the homogeneous particles of the substance. It is not yet possible however to determine inversely the distribution from the experimentally determined after-effect function.

A more extensive relationship between resistance to deformation and colloid-chemical properities has been found by the investigation of sols and gels. It is well known that for these substances or states the viscosity as measured by Poiseuille's method is not a material constant, being dependent upon the conditions of the experimental procedure. Neither Poiseuille's law nor Reynold's law of dynamical similarity is valid. The law of flow for these substances can, however, be referred back to the dependence of the fall in velocity upon the shearing force (pressure)[8]. By the application of this relationship the dependence of the volume of flow upon the fall in pressure can be calculated from its dependence upon the diameter of the outflow tube and the way is thereby prepared for a generalisation of Reynold's law to include sols.

The present investigation seeks on the other hand to further test the various theories of elastic after-effect by the investigation of flow and relaxation, and on the other hand to add to the knowledge of the mechanical-physical behaviour of single filaments.

Previous measurements on textile fibres relate chiefly to stress-strain curves, of which those made by I. Karger and E. Schmid[9] on viscose rayon, cotton, wool, and natural (Tussah) silk at different degrees of swelling are especially interesting. The curves for each type of fibre show a characteristic form. In the case of viscose, swelling caused changes in the form of the curve as well as in the magnitude of the elongation or strain. The influence of the rate of extension on the form of the curve was slight for speeds varying within the ratio of 1:60. Speakman[10] has also studied the effect of humidity and of temperature on the stress-strain relationship in wool and has discussed at some length in this and other papers[11] [12] the after-effect phenomena in this fibre. In one of these,[12] he has measured the flow of wool fibres under constant stress by means of the hyperbolic weight method of Andrade.

Peirce[13] measured the after-effect in cotton yarn by a torsional method similar to that employed by Kohlrausch. Mann and Peirce[14] have studied the relationship between the time required to break a cotton hair and the breaking load. Assuming that the extension at break is constant regardless

of the rate of loading (as their measurements indicate) they point out that this relationship represents the relaxation curve for the fibre which is held at a constant extension just below its extension at break. In a later paper Peirce[15], in a general discussion of elastic after-effects, gives a similar curve for a viscose filament.

Weltzien[16] has made an investigation of the relationship between mechanical properties of rayon and degree of swelling. His results, in so far as they are important to the present work, are reported in the section on "pretreatment of the filaments."

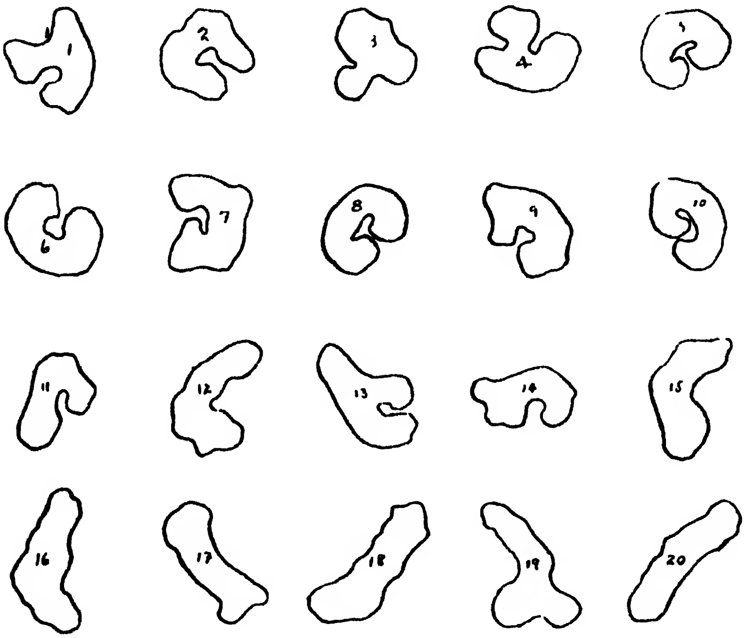


FIG. 1

Cross Sections of Commercial Viscose Rayon.

EXPERIMENTAL PART

Material

The majority of the experiments were made on single filaments from two different viscose rayon samples. The first was a skein of commercial viscose rayon composed of 21 filaments, with a nominal denier of 150 and a twist of 2½ turns per inch. This sample is hereafter referred to as "commercial viscose rayon." The second was a skein of viscose rayon which was especially produced through the courtesy of the Glanzstoff plant in order to provide as circular a cross section as possible. The yarn was composed of 24 filaments. This sample is hereafter called "Glanzstoff viscose rayon." The single filaments were carefully separated by means of a needle after untwisting a length of approximately 25 cm. of yarn.

In addition to these materials, single experiments were also made on a cellulose acetate filament produced in the laboratory, and on a filament of natural silk from a boiled-off cocoon of Bombyx mori.

It is difficult to establish a well defined initial condition of the filaments. In the first place the cross section is not circular nor is it uniform along the filament; secondly, the curliness and bends, caused during the manufacture and subsequent handling of the filaments, add difficulties to the determination of stress-strain relationships. A third factor which is also due to the past history of the sample is the presence of internal strains which may be irregularly distributed along the filament.

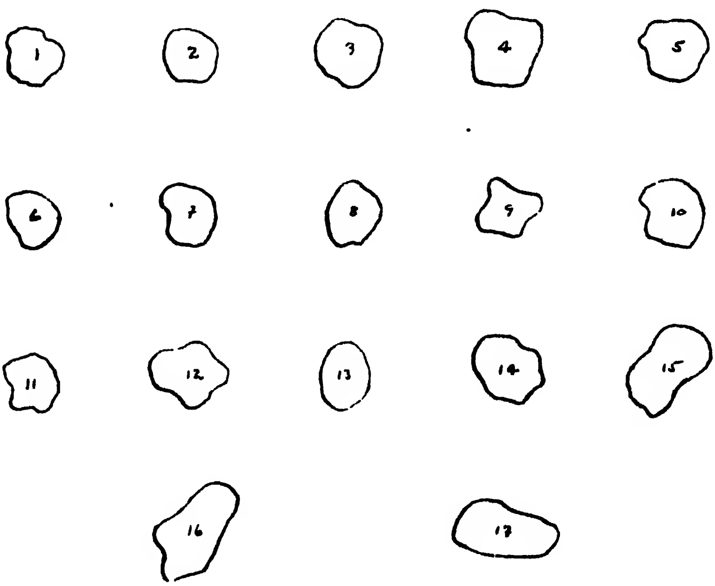


FIG. 2

Cross Sections of Glanzstoff Viscose Rayon

Determination of Cross Sectional Area

Other workers investigating the stress-strain relationship of single filaments of rayon[9,17] have applied a mean value for the area of the filament cross section to each single filament tested.

An investigation of the shape of the cross sections of both commercial viscose (Fig 1) and Glanzstoff viscose (Fig. 2) filaments showed that they were not circular and that no reliable relationship between cross sectional area and length of fibre axes (or axis ratio) existed in either case. Hence it was impossible to estimate accurately the sectional area from simple lateral measurements with an ocular micrometer of the width and thickness of the filaments. This left open the alternatives of cutting and measuring sections from each individual filament tested or of applying a mean value to all tests, of which the latter was chosen after the following measurements had been made.

Table I summarises the results of measurements on the commercial viscose sample.

Table I

	Sectional area in room atmosphere (μ^2)	Sectional area calculated to dry condition (μ^2)
Calculated from weight of 1 meter—		
At 50% Rel. Hum.	507	470 (based on 2% shrinkage lengthwise and 9% moisture regain at 50% R. H.).
At 57% Rel Hum.	527	473 (based on 2% shrinkage lengthwise and 12% moisture regain at 67% R. H.).
Measurement of 20 individual sections—		
Smallest	472	
Largest	674	
Mean	534	507 (based on 5% contraction in area of section upon drying).

Examination of sections of 17 individual filaments of the Glanzstoff viscose sample revealed a more circular form but still greater variation in area, namely, from $385\mu^2$ to $632\mu^2$. Lateral measurements of the axis ratio of each filament actually used for test revealed that the ratio in each case corresponded approximately to those of section 11, 15, 16 and 17, whose average area is $556\mu^2$ in the room atmosphere or $528\mu^2$ calculated to the dry condition.

Because of this considerable variation displayed by both the commercial and the Glanzstoff samples, a rounded value of 500 μ^2 was used for each in calculating stresses.

The cross sections of the cellulose acetate and the natural silk filaments were approximately circular and were therefore calculated from the mean of 15 to 20 lateral measurements of the diameter. The mean area of the cellulose acetate filament was $675\mu^2$ and for the natural silk filament $106\mu^2$.

Pretreatment of the Filaments

In order to produce a definite initial condition it is necessary to place the filament under such a load that the flexure elasticity of the curliness and the bends along its length are overcome without actually stretching it. Such an ideal condition can only be approximated because the two effects actually overlap.

The first essential is to select the filaments for straightness. In order to straighten the filament and release or equalise inner strains, these are then subjected to a swelling in water under a very small load and subsequent drying. This procedure is based in part on the observations of Weltzien[16], who found that the changes in length of viscose yarns, under very light load upon swelling in water and redrying, are fully reversible. A yarn on the other hand which has suffered a permanent change in length of one per cent by reason of previous extension, does not increase in length as much as an unstretched yarn upon swelling; upon redrying it shortens more than the unstretched yarn and recovers thereby a portion if its previous "permanent" stretch, but this new dry length is thereafter retained at the end of every subsequent cycle of swelling and drying. These observations indicate that the inner strains which are present in the material, due to previous stresses, may be at least partly equalised or removed by swelling in water. In order to remove the curliness at the same time the filament must be under a very

small load during the swelling and drying process. Finally the application of an initial load to the air dry filament during the mounting operation and at the start of the experiment increases the uniformity of the initial or "zero" condition of the filament. This load is unobjectionable since the resulting stress is below the limit of observation.

In the experiments on the Polanyi apparatus the filaments were not pretreated. The procedure for filaments tested on the relaxation apparatus was as follows—The filament, loaded with a minute droplet of pitch on its lower end, is lowered into a tall cylinder of distilled water for a few minutes, (experiments by Obermiller[17] have shown that viscose filaments are fully saturated within one minute after immersion) slowly withdrawn and allowed to hang in the air until air-dry. The filament is then laid on a smooth and preferably dark surface and the pitch droplet replaced by the tiny length of wire which serves as the initial load as mentioned above The magnitude of this initial load was so chosen as to produce a tension of approximately 0·1 kg/mm² in the filament. For both viscose samples and for the acetate filament a weight of 50 mgms. was used; for natural silk 10 mgms. The entire operation of mounting the filament is so conducted that this tension is not exceeded and the initial length of the filament is measured under it.

Table II

Effect of Pretreatment of Filament on the Stress Measurements

COMMERCIAL VISCOSE RAYON—DRY CONDITION

Load (grm)	% Strain per grm of load	Experiment No
Without pretreatment		
1·00	0·256	13
1·61	0·326	28
3·97	0·207	14
After pretreatment—		
1·07	0·233	51
1·09	0·248	50
2·00	0·185	47a
2·10	0·181	47
2·11	0·171	46
3·07	0·167	53
3·12	0·175	48
3·20	0·176	49

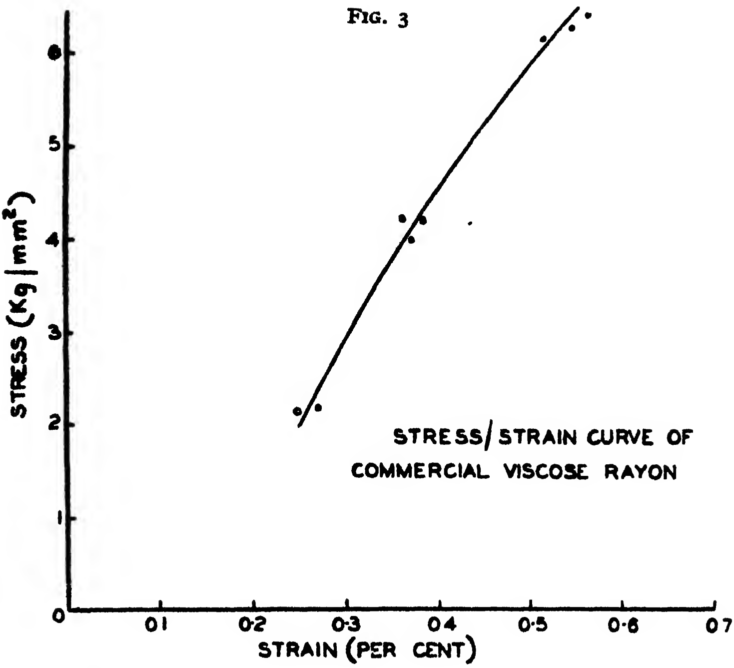
GLANZSTOFF VISCOSE RAYON—DRY CONDITION

Load (grm)	% Strain per grm of load	Experiment No
After-pretreatment-		
0·95	0·216	61
0·95	0·201	62
1·06	0·194	56
1·86	0·168	64
2·09	0·186	52
3·12	0·198	57
3·20	0·175	58

Table II gives a number of stress measurements made on treated and untreated filaments An approximate determination of the modulus of elasticity may be obtained by determining the extension as soon as possible after loading the specimen, as was done in obtaining these figures, which are also recorded graphically in Figs. 3 and 4 (curve 1). Fig. 4 shows that for the Glanzstoff filaments, after pretreatment, the strain is proportional to the load, although the straight line does not intersect the axes exactly at the zero point. It is probable that some curliness is still present in the pretreated filament, amounting to about 0·03% of the length.

Due perhaps to irregularity in its cross section, the curve of the commercial viscose rayon is not straight. The spread of determinations is nevertheless smaller than in the case of the untreated filaments. In spite of the slight residual curliness the pretreatment was not made more severe in order to avoid danger of altering the properties of the material.

FIG. 3


STRESS (Kg/mm²)
STRESS/STRAIN CURVE OF
COMMERCIAL VISCOSE RAYON
STRAIN (PER CENT)
0
1
2
3
4
5
6
0·1
0·2
0·3
0·4
0·5
0·6
0·7

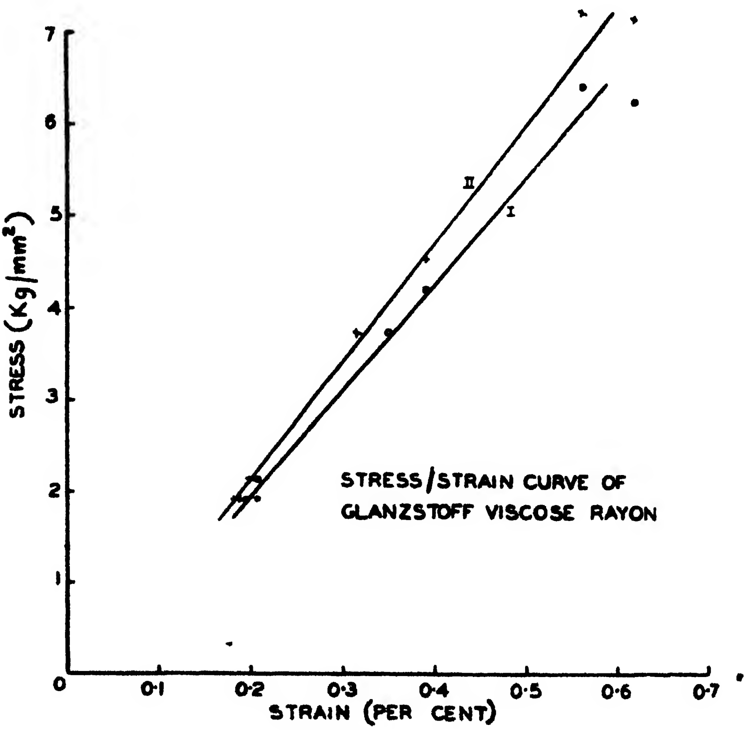

STRESS (Kg/mm²)
STRESS/STRAIN CURVE OF
GLANZSTOFF VISCOSE RAYON
II
I
STRAIN (PER CENT)
0
1
2
3
4
5
6
7
0·1
0·2
0·3
0·4
0·5
0·6
0·7

FIG 4

Experimental Technique

The first group of flow experiments of the commercial rayon sample were made on an improved model of the Polanyi tester, the second group of flow and relaxation experiments were made on apparatus developed expressly for the purposes of this work. These have both been described in a previous paper,[18] which describes also the preparation of the dry air and the methods of controlling the atmosphere, or medium surrounding the filament, and the temperature.

On the Polanyi apparatus the filament was mounted and conditioned slack. In order to prevent cutting at the jaws it was laid in a fold of a small strip of paper thinly coated with pitch and this was clamped between the jaws. After drying the specimen in the dry air stream for several hours, preferably overnight, the initial length was determined by lowering the micrometer screw by means of the calibrated wheel until the first perceptible deflection of the spring was observed in the telescope.

The flow experiment was then conducted as described in the previous paper, two observers being necessary—one to load the filament and then maintain the load at a constant value by continuous observation of the telescope reading and corresponding manipulation of the calibrated wheel; the other to observe and record the readings of this wheel and of the time. After the first few minutes the decreasing rate of flow made it possible for the first observer to continue the experiment alone, observing and recording all data.

On the relaxation apparatus the filament was mounted under an initial load which produced a tension of about 0·1 kg/mm^2 as noted above. Because of the limited permissible swing of the balance beam the mounting operation was so conducted as to accurately control the initial length of the specimen as well as to limit the tension in the filament, during the operation of mounting, to that produced by the initial load. This was accomplished by balancing the wire weight hanging on the lower end of the filament by an equal weight placed on the right end of the beam. At the conclusion of the mounting operation the balance beam was lowered to rest, in which position the specimen was quite slack during the drying period.

Procedure for a Flow Experiment on Relaxation Apparatus

Before mounting the specimen the balance beam, inclusive of clamp (*a*), must be brought into equilibrium (by regulating the running weights on the beam ends) with the pointer on zero (middle line) of its scale. The telescope reading for this position is recorded as "zero reading" It corresponds to a length of specimen of 145 mm.

After the specimen has been mounted and sufficiently dried by the dry air stream, the balance is again released and the telescope reading recorded as the "dry unloaded" reading (specimen is under the initial load due to the wire weight which is still on the right hand end of the beam). From this reading the dry initial length of the specimen is calculated. The initial weight is left on the beam during the entire experiment and simply added to the applied load.

The desired weight is placed on the floating dish and connected loosely to the hook (*p*) by means of its silk filament.

One observer is sufficient. Alcohol is let out of (*o*) rapidly until the weight hangs free on the beam hook. The instant at which it hangs free is zero time. The observer makes observations of the telescope scale reading against time as often as practicable at first, later at increasing intervals. From these readings the changes in length are calculated and plotted against the time.

Procedure for a Relaxation Experiment

The "zero" and "dry" readings are made as described under "flow experiments."

The initial weight is then carefully removed from the right end of the beam (this may best be accomplished by seizing a short length silk filament previously tied to the weight, thus avoiding the transference of shock to the beam through rigid forceps). Alcohol is then run slowly out of (*o*) until the pull of the float brings the beam back to the "dry unloaded" telescope scale reading.

A tared beaker is placed on one pan of the balance below the outlet tube (*v*), and on the other pan weights equal to the weight of alcohol which must flow out of (*o*) in order to produce the desired load on the specimen.

Two observers are necessary. One notes the burette reading before the start of the experiment, allows alcohol to flow quickly from (*v*) into the tared beaker until the balance justs tips, closes (*v*) carefully but quickly and then reads the burette and notes these readings and the time at intervals as directed by the second observer. The second observer reads the telescope and the time. The first telescope scale reading under load is held as constant as possible during the entire experiment by allowing alcohol to flow into (*o*) from the burette (*r*). Since it is impossible to avoid a slight variation in the telescope reading (amounting to about 0·03 cm.), the readings of the burette by the first observer and of the time by the second are best made at the command of the second at the moments when the telescope reading has been brought back to the correct point. The first readings should follow one another as rapidly as possible, later as the process slows down, the intervals between readings may be correspondingly lengthened.

The telescope reading must also be recorded as it is essential for the calculation of the loaded specimen length.

In the experiments up to No. 56 the moment of closing the outflow tube (*v*) was taken as zero time. In later experiments zero time was the time of the first loaded reading.

RESULTS

Experiments on the Effect of Swelling and of Temperature on the Rate of Flow

Table III provides a summary of the conditions under which the several experiments in this group were made.

In all these experiments every effort was made to obtain the first part of the curve from the earliest possible moment after loading, since it is to be expected that the simplest relationship will be found there. For this reason the filaments were not pretreated and were mounted under no initial load, in spite of the fact that this reduced the accuracy of the determinations because of the possible errors due to internal strains and to the curliness in the filament which interferes with the exact determination of the absolute extension. Only that portion of the flow curve after the attainment of the full load was recorded.

For the observation of the effect of swelling on flow, experiments 13, 14, 18, 28, and 40 were made on carefully dried filaments, experiments 15, 25, and 27 in water, and 24 and 26 in glycerine.

Table III

Conditions of the Experiments on the Influence of Swelling and Temperature on the Rate of Flow

Material—Commercial Viscose Rayon. *Apparatus*—Polanyi Tester.

Exp. No.	Medium in which filament was tested	Temperature °C.	Load gms.	Duration of Experiment
18	Dry air	Room temp.	0·24	3½ minutes
13	,,	19	1·00	13 ,,
28	,,	22	1·61	2¼ ,,
40	,,	20	2·01	22 ,,
14	,,	20	3·97	3 hours
23	Water	Room temp.	0·30	25 minutes
27	,,	22	0·35	2 ,,
15	,,	18	1·00	2 hours
26	Glycerine	Room temp.	0·31	2¾ minutes
24	,,	18	0·36	3¾ ,,
43	Dry air	114	1·98	14 ,,
42	,,	−75	1·98	24 ,,
41	,,	−180	1·98	2½ ,,

In experiments 13, 14, and 15, the length tested was 25 mm ; in the remainder it was approximately 100 mm

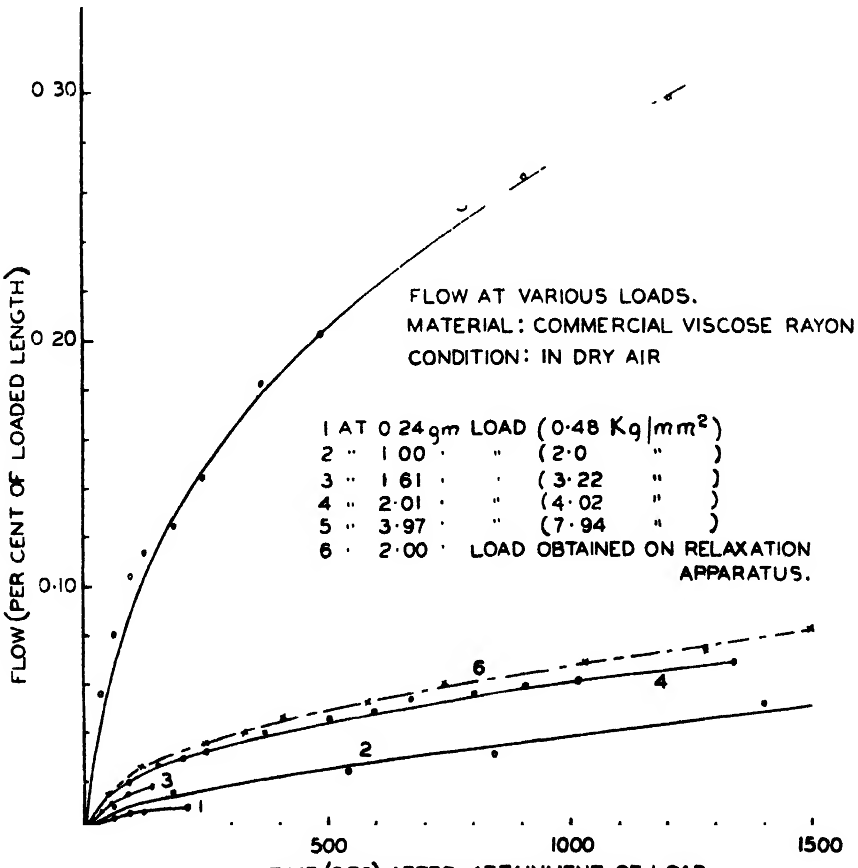


Fig 5

Table IV

Summary of the Conditions under which the Flow Experiments on the Relaxation Apparatus were made

Exp. No.	Material	Medium in which filament was tested	Temperature ° C.	Load grms.	Duration of flow observations	Duration of recovery observations	Remarks
47a	Commercial viscose	Dry air	20°	2·00	25 min.	--	Comparable to Exp. 40 on Polanyi apparatus
61	Glanzstoff viscose	,,	Room temp.	0·95	65 ,,	3·4 hrs.	
62	,,	,,	,,	0·95	65 ,,	5·0 ,,	
56	,,	,,	22°	1·06	31 ,,	3·6 ,,	
63	,,	,,	Room temp	1·86	63 ,,	18·0 ,,	
					60 ,,	16 min.	*Second cycle following directly upon first.
					60 ,,	3·0 hrs	Third cycle after repeating the pretreatment of the filament (swelling and drying at the conclusion of the second cycle)
64	,,	,,	,,	1·86	58 ,,	3·8 hrs.	
					32 ,,		Second cycle following directly upon first
					60 ,,	3 hrs	Third cycle after repeating the swelling and drying pretreatment at the close of the second cycle
59	,,	In air of 28% R.H.	21°	1·05	11 ,,	-	

The difference between these flow experiments and those performed on the Polanyi apparatus consists essentially in the reduction of the sources of error due to the Polanyi apparatus. The fluctuation in load which is unavoidable in that apparatus is entirely absent here, as are also the errors due to friction and oscillation of the flat spring. The duration of the loading operation is independent of the load and can be reduced to a fraction of a second. Nevertheless an interval of several seconds elapses before the first reading can be taken because of the elastic oscillations of the specimen and beam. By means of the previously described oil damping, the time to the first reading was reduced to 11 seconds.

The errors due to the undefined condition of the specimen itself, although not entirely eliminated, are greatly reduced by the pretreatment to which each of the filaments was subjected. The uncertainty due to variations in cross section from filament to filament and within one filament remains.

*This experiment consists of three flow and two recovery curves, whose forms agree satisfactorily with the parallel experiment 64. Nevertheless, for some unexplained reason, the absolute strain as shown in the first and second cycles is about 50% greater than that of the third cycle, as well as that of the parallel experiment, and does not check with other strain determinations. As it seems very probable that this is due to an error in the reading of the initial length, this experiment has been evaluated by assuming that the strain at the first point is the same as the corresponding strain in the parallel experiment.

Comparison of the experiment 47a with experiment 40, which was made on the Polanyi apparatus (Fig. 5), shows as good agreement as may be expected in view of the difference in pretreatment.

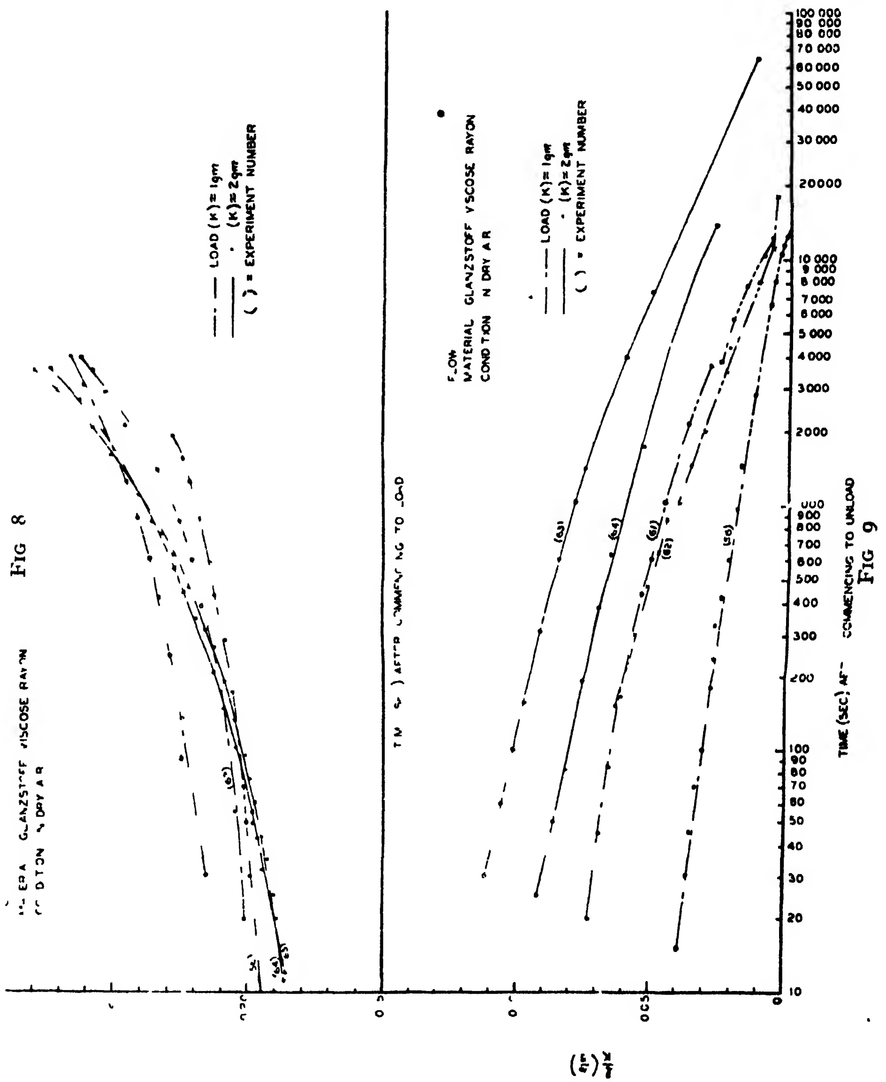


FIG. 8 FIG. 9

Experiments 56, 61, 62, 63, and 64 are plotted in Fig. 8 with the strain per. gram load as ordinate and the logarithm of the time as abscissa. Comparison of the experiments at 1g. and 2 g load seems to show a systematic deviation, in that the rate of flow per gram is greater at a 2 gram load than at a 1 gram load. It cannot be determined with certainty just where the curves at 1 gram and 2 grams intersect because of the spread of the initial stresses.

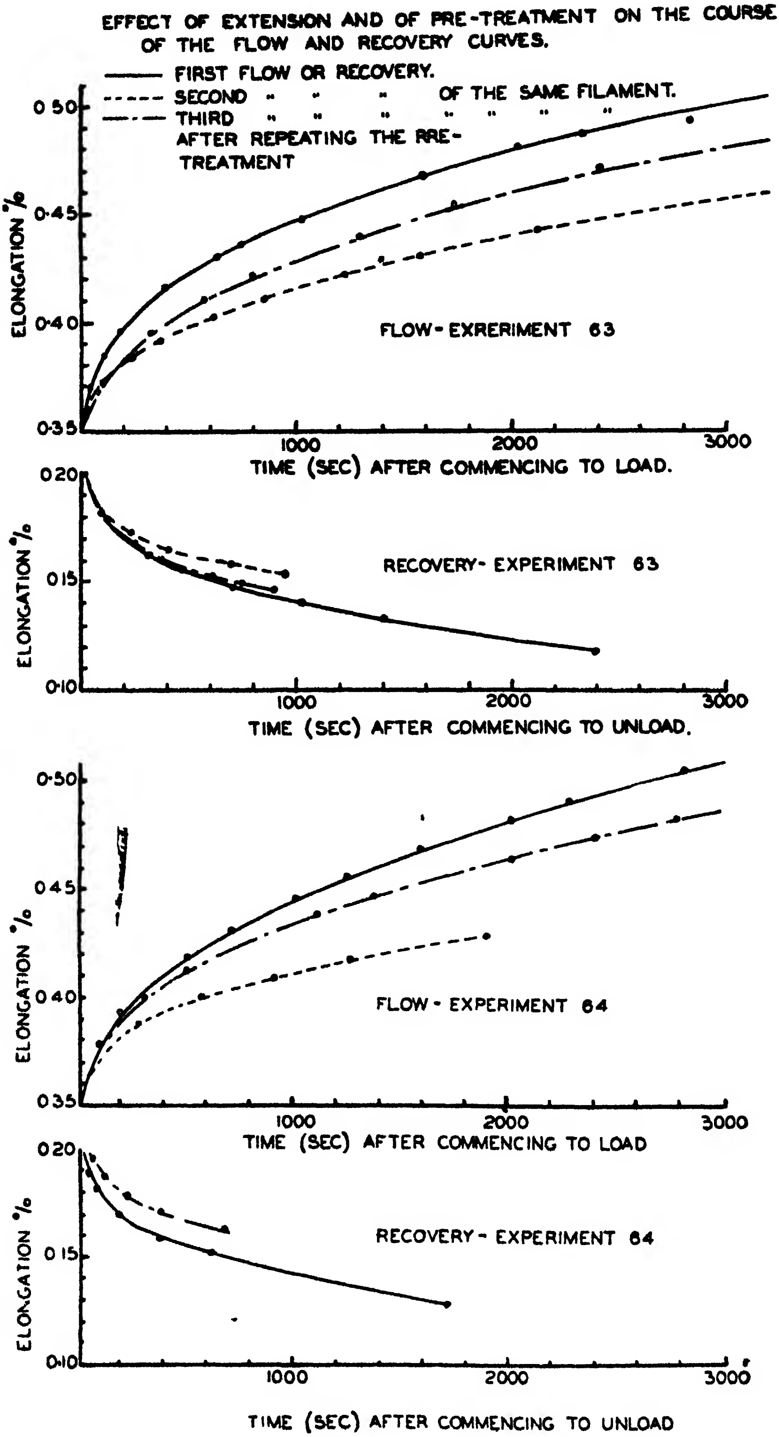

EFFECT OF EXTENSION AND OF PRE-TREATMENT ON THE COURSE OF THE FLOW AND RECOVERY CURVES.
FIRST FLOW OR RECOVERY.
SECOND " " " OF THE SAME FILAMENT.
THIRD " " " " " " "
AFTER REPEATING THE PRE-TREATMENT
ELONGATION %
0·50
0·45
0·40
0·35
FLOW-EXRERIMENT 63
1000
2000
3000
TIME (SEC) AFTER COMMENCING TO LOAD.
0·20
0·15
0·10
RECOVERY-EXPERIMENT 63
TIME (SEC) AFTER COMMENCING TO UNLOAD.
FLOW-EXPERIMENT 64
TIME (SEC) AFTER COMMENCING TO LOAD
RECOVERY-EXPERIMENT 64
TIME (SEC) AFTER COMMENCING TO UNLOAD

Fig. 10

In experiments 61, 62, 56, 63, and 64, after approximately one hour flow (one half hour in No. 56) the filament was quickly unloaded to the initial load and the recovery observed for several hours. In experiment 56 the filament which had flowed for one half hour at a load of approximately 2·1 kg. per sq. mm. recovered its original length at the end of three and a half hours.

Fig. 9 shows the recovery curves with the strain per gram load plotted against the logarithm of the time. The curves display a decided spread in the absolute values of the length, but the curves made at two grams load run nearly parallel. Two of the curves made at one gram load are also approximately parallel with curves made at two grams while the third one gram curve is flatter. In the last section a test of the interrelations of these flow and recovery curves, according to Boltzmann's theory, is given.

The relatively large variations in all these experimental results are presumably due in part to the variation in the cross sectional area of the filaments and in part to the indefiniteness of the initial condition which exists to some extent in spite of the pretreatment.

In order to further investigate this point, the filaments in experiments 56, 63, and 64 were subjected to a second cycle following upon the first and consisting also of rapid loading to the load attained in the first cycle, flow, unloading to the initial load and recovery. In all three experiments, the second flow curve is less steep than the first, i.e., the mechanical properties of the filament have been altered by even the small strain here applied. In order to test whether this alteration could be eliminated by the pretreatment as here used, the filaments in experiments 63 and 64 were carefully removed from the apparatus and again subjected to the pretreatment, i e., immersed in water, dried in air and then remounted and again dried out thoroughly in the dry air stream. A third flow curve made at the same load as before following this treatment lies, in each experiment, between the first and the second (Fig. 10), showing that the original condition of the filament was only partially regenerated by this treatment.

This result is analogous to that of Weltzien on filaments which had been permanently stretched. It indicates that by means of the applied pretreatment mechanical variations in the filament, due to previous stresses, are at least partially released and equalised. It is evident, however, that the treatment was not drastic enough to fully eliminate the differences. Although this uncertainty in the initial condition is unquestionably a cause of the spread of the experimental results, a more drastic pretreatment was avoided in order to prevent the alteration of the material before testing.

Apart from the difference in the stretch, experiment 63 shows that the second recovery curve is flatter than the first in its later portion (Fig. 10), i.e. the alteration in the mechanical properties is apparent here also. The third recovery curve (after repeating the pretreatment) lies nearer to the first but is noticeably flatter.

Experiment 59, which was made in air of 38% relative humidity, shows at each point along its entire length (11 minutes) a rate of flow which is approximately four times as great as that of the dry material (Fig. 11).

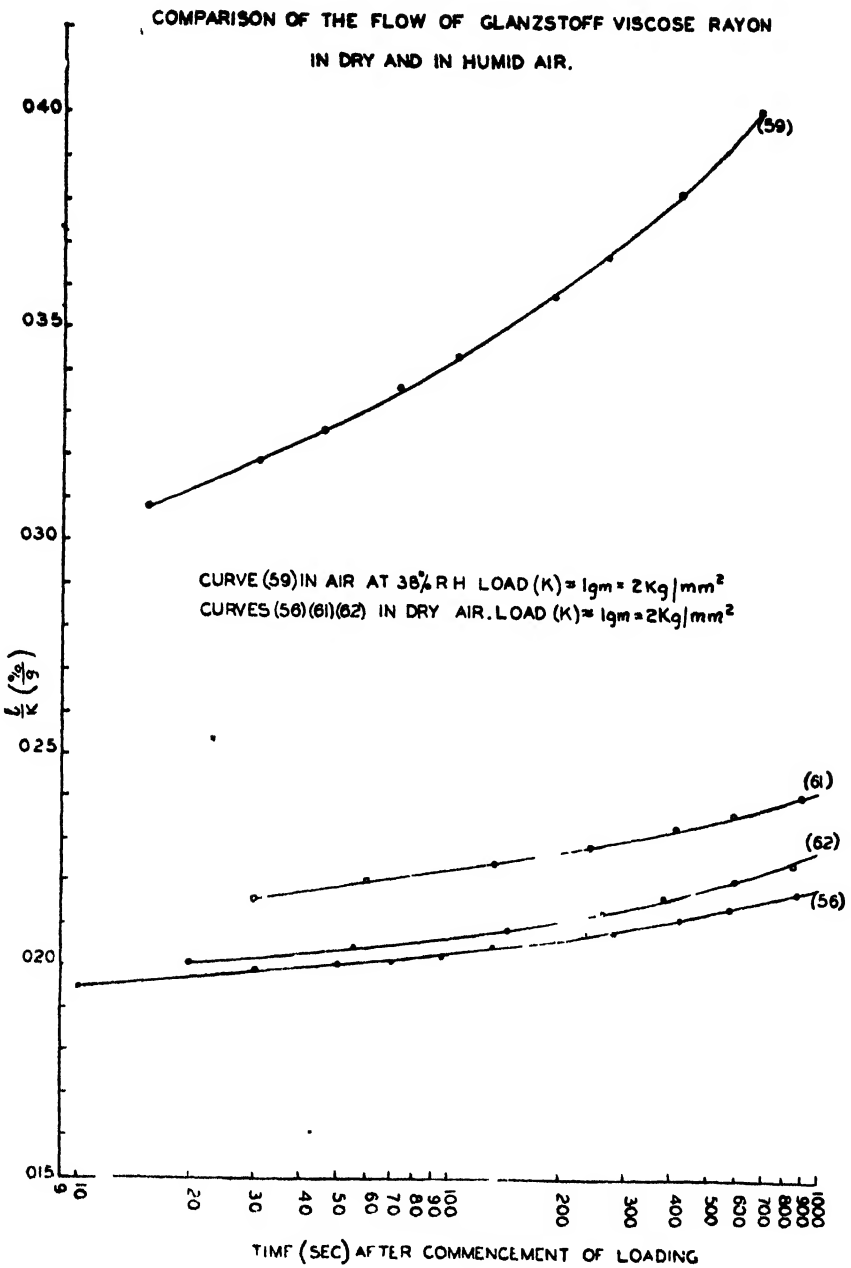

COMPARISON OF THE FLOW OF GLANZSTOFF VISCOSE RAYON
IN DRY AND IN HUMID AIR.
CURVE (59) IN AIR AT 38% R H LOAD (K) = 1gm = 2Kg/mm²
CURVES (56)(61)(62) IN DRY AIR. LOAD (K) = 1gm = 2Kg/mm²
(59)
(61)
(62)
(56)
040
035
030
025
020
015
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
TIME (SEC) AFTER COMMENCEMENT OF LOADING

Fig 11

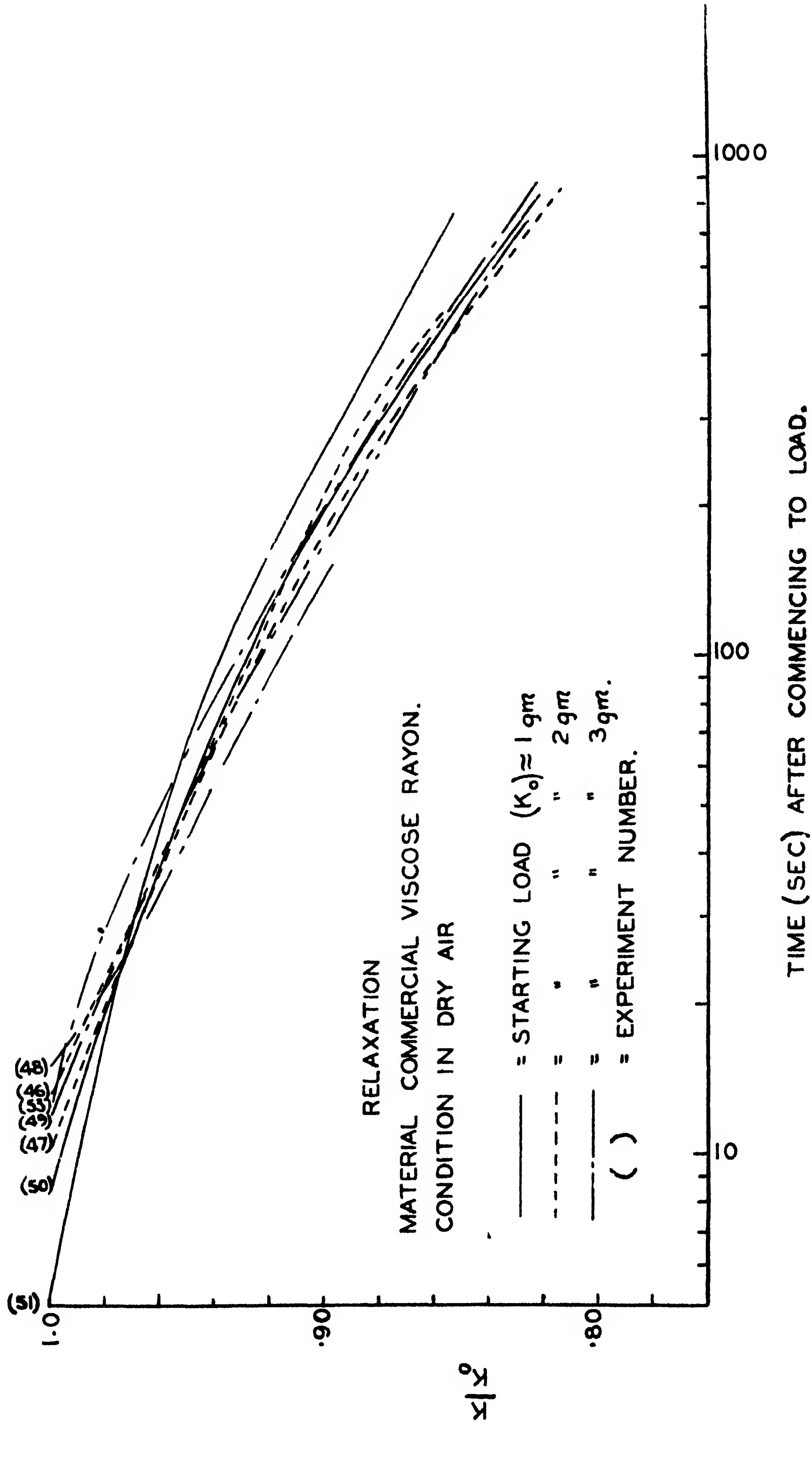

RELAXATION
MATERIAL COMMERCIAL VISCOSE RAYON.
CONDITION IN DRY AIR
= STARTING LOAD $(K_o) \simeq 1$ gm
" " " 2 gm
" " " 3 gm.
( ) = EXPERIMENT NUMBER.
(48)
(46)
(53)
(49)
(47)
(50)
(51)
1.0
.90
.80
$\frac{K}{K_o}$
10
100
1000
TIME (SEC) AFTER COMMENCING TO LOAD.

FIG 12

Relaxation Experiments—The following table summarises the conditions under which the relaxation experiments were made—

Table V

Summary of Conditions under which Relaxation Experiments were made

Exp. No.	Material	Medium in which filament was tested	Temperature ° C.	Starting load grms.	Duration of experiment	Remarks
51	Commercial viscose rayon	Dry air	21	1·07	13 mins.	
50	,, ,,	,,	19	1·09	14·3	
46	,, ,,		19	2·11	8	
47	,, ,,		19	2·10	14·6	
53	,, ,,		23	3·07	16·3	
48	,, ,,		21	3·12	10·7	
49	,, ,,		22	3·20	12·3	
52	Glanzstoff viscose rayon		23	2·09	10·4	
57	,, ,,		20	3·12	50	
58	,, ,,		20	3·20	64 ,,	This fibre, after pretreatment and mounting in the apparatus, was extended a few times to 6% in the atmosphere of the room, then released and dried, and tested in the usual manner
60	,, ,,	Air of 38% rel. hum	22	1·08	40 ,,	
54	Cellulose ... acetate fil.	Dry air ...	21	2·06	12 ,,	
55	Natural silk fil.	,,	...Room temp.	1·03	11·4 ,,	

All relaxation curves are so plotted that the ordinates are the momentary load divided by the starting load, i.e. the load at any instant expressed as a decimal of the starting load. The abscissæ are the log. of the time.

Figs. 12 and 13 represent the relaxation curves at different loads. It is evident from the grouping of the curves in Figs. 12 and 13 that the relaxation is largely independent of the load. In order to decide how exactly this condition is fulfilled, an examination of the possible sources of error is necessary.

The grouping of the curves indicates that the influence of variations in cross section, which is a cause of much uncertainty in flow measurements, is of minor importance here. Although places of different cross section along the filament are under different absolute stress, they must relax at about the same rate. The variation in the time interval from the beginning of the application of the load to the first reading is a source of error whose influence is difficult to estimate. During this time the filament flows, at first under a small load, later under the full load. In the experiments made with 1 gram starting load (Nos. 50 and 51), the course of the curves is different in spite of approximately equal elapsed times up to the first reading. This discrepancy is possibly due to differences in the initial condition of the material. The curves of the commercial viscose rayon in Fig. 12 give the impression that the relative rate of relaxation tends to increase slightly with increasing starting load; the curves for Glanzstoff rayon, in Fig. 13, show the opposite trend. It is most probable that these apparent trends are due

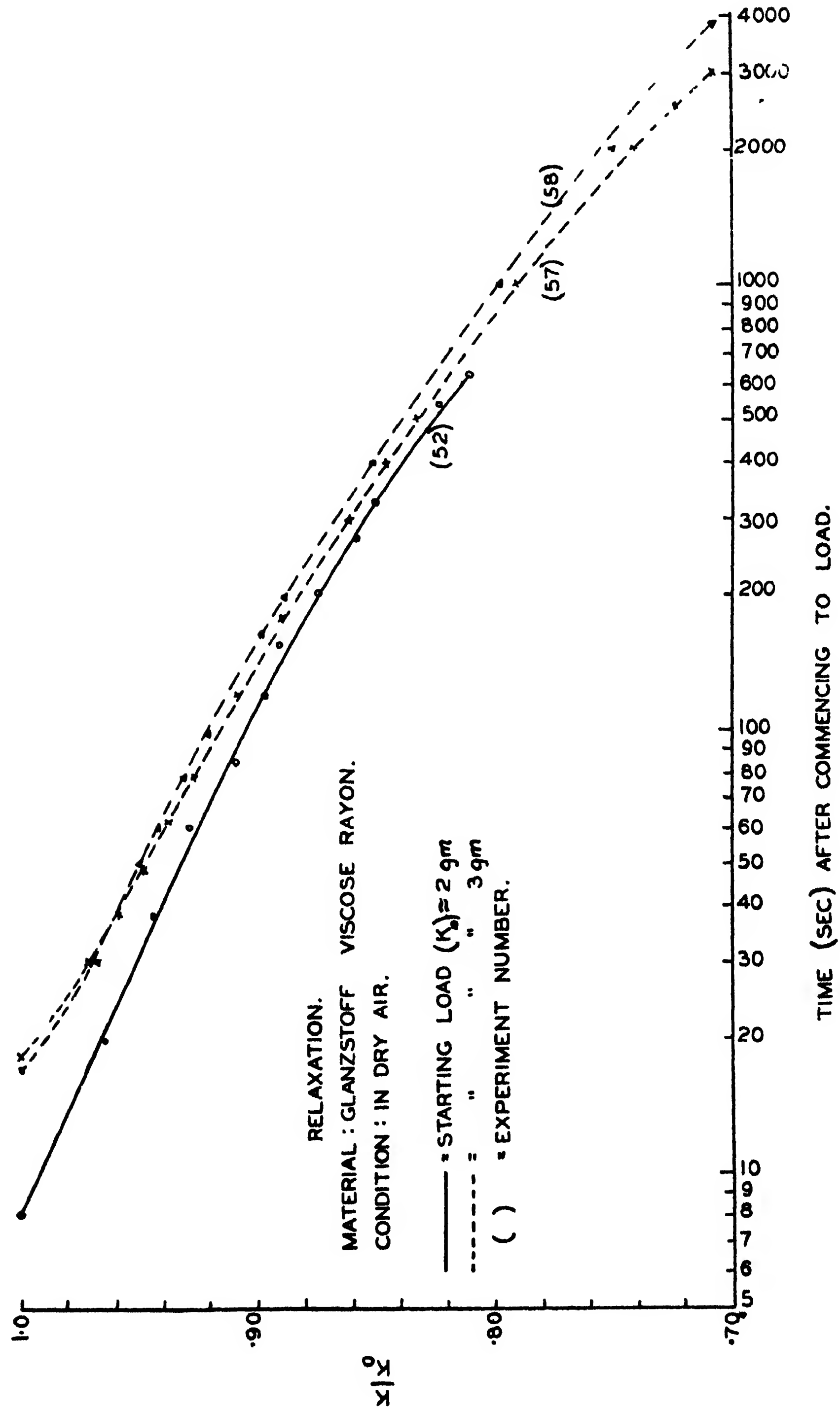

RELAXATION.
MATERIAL : GLANZSTOFF VISCOSE RAYON.
CONDITION : IN DRY AIR.
= STARTING LOAD (K₀) = 2 gm
" " " 3 gm
( ) = EXPERIMENT NUMBER.
(52)
(57)
(58)
K/K₀
1·0
·90
·80
·70
5
6
7
8
9
10
20
30
40
50
60
70
80
90
100
200
300
400
500
600
700
800
900
1000
2000
3000
4000
TIME (SEC) AFTER COMMENCING TO LOAD.

FIG 13

to the inevitable scattering of results, and that the course of the curve is independent of the starting load.

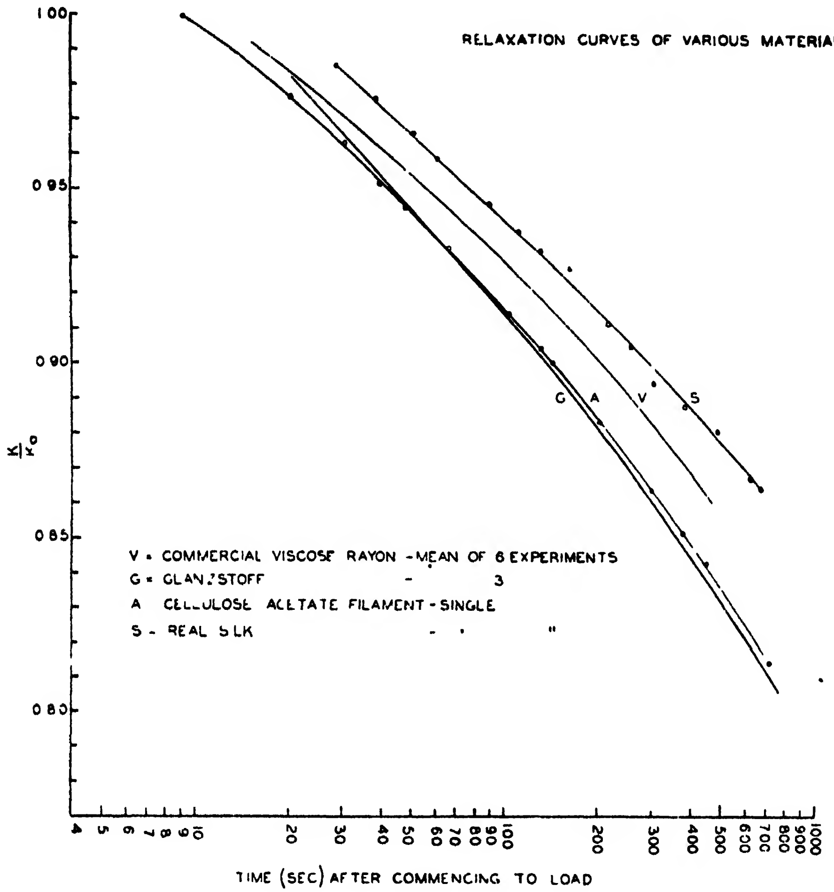


FIG 14

In Fig. 14 the mean curves for the commercial viscose and for the Glanzstoff samples are plotted, together with the single curves obtained from a cellulose acetate filament and from real silk. The approximate parallelism of the four curves is conspicuous.

Experiment 60, which was made in air of 38% relative humidity at 22° C., shows on the average a relative relaxation at all points between 50 and 1,000 seconds of about 1·3 times that of the dry filament (Fig. 15).

According to this experiment and experiment 59, which was made at approximately the same humidity, the flow is affected more strongly than the relaxation by swelling (four times for flow as against 1·3 times for relaxation) although the nature of the effect is the same in both cases, i.e. the difference is simply quantitative in reference to the velocity of the phenomena without producing any marked change in the form of the curve.

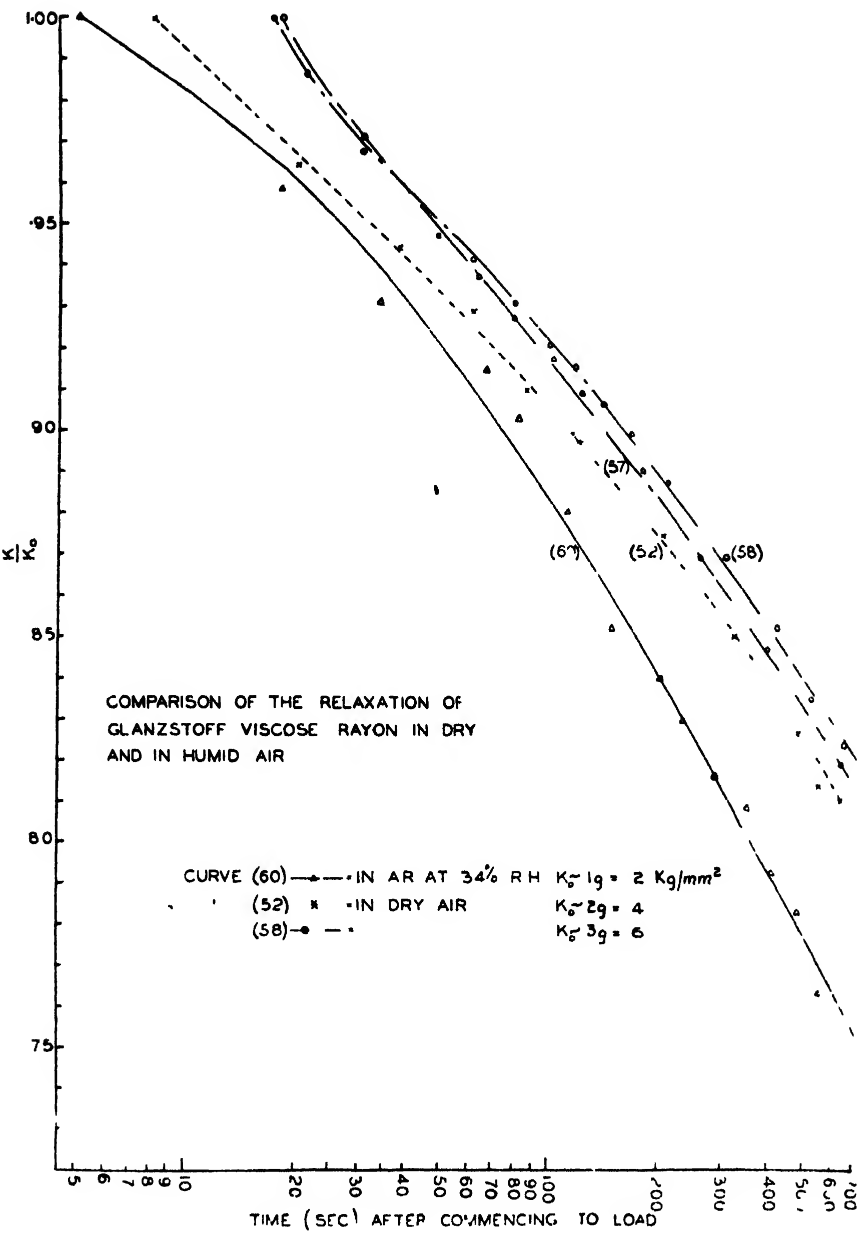


FIG 15

Discussion of the Results

The outstanding result of the relaxation experiments is the great probability that the relative rate of relaxation is independent of the initial load. This relation is in accord with the Maxwell theory and makes it probable that the Maxwell relaxation equation holds true for the small plastic homogeneous regions. The form of the relaxation curves is not in

agreement with the Maxwell theory. In comparing the experimental results with the inferences from the Boltzmann theory, the following criteria exist—

(*a*) The relaxation should be proportional to the extension (equation 6).

(*b*) The flow should be proportional to the load (equation 4).

(*c*) The recovery should, in the first portion of the curve, be proportional to the load (equation 5).

(*d*) The after-effect function, calculated from the relaxation curve, should determine the shape of the flow and recovery curves: that is, the proportionality factor β in equations 4, 5, and 6, should have the same value.

The relaxation curves satisfy the first requirement, since, as already deduced, the rate of relaxation is proportional to the initial load, and this in turn is approximately proportional to the extension.

On the other hand, the course of the flow curves is not in agreement with the second requirement, since the rate of flow increases faster than the initial extension or load, as shown by the curves at one and two grams load in Fig. 8. The rate of flow under two grams load for the whole period of observation is more than double that under one gram, although the starting point of the former is lower, due to the variation of the initial extension. It should be noted that in spite of the uncertainty of the initial condition of the filament and the variation in cross section, this effect appears to be real. It is not in accord with the Boltzmann theory, not even for any possible after-effect function which may fit the latter.

The recovery curves run (within the limit of experimental error) approximately proportional to the initial load, in agreement with the third requirement.

Since the Boltzmann theory does not hold for the flow curves, a conversion of the flow, relaxation, and recovery curves into one another according to criterion (*d*) cannot lead to exact results. In the previous investigations of the elastic after-effect which have been discussed in the introduction, experience has shown that in those instances where the Boltzmann theory holds, a logarithmic course of the curve is to be expected, at least approximately, thus—

$$\int_0^t \varphi(t - z)dz = ln\, t \text{ (for } t > 1).$$

In the present experiments this relation is in fact also approximately fulfilled for the early part of the curves. A systematic deviation appears later, i.e. the rate of flow increases more rapidly than the logarithmic function. No more accurate expression for the after-effect function was sought since the Boltzmann theory does not fit perfectly here.

This theory may be tested *by comparison of the flow curves with the relaxation and recovery curves*. Since the flow curves satisfy the logarithmic law in their first portion (between 30 and 100 sec.), the others should also. Figs. 8, 9, and 13 show that *the unloading and relaxation curves do, in fact, confirm this prediction*, that is, equations 4, 5, and 6 pass over into the following forms (in which common logarithms are used instead of the natural).

$$\text{Flow} \qquad l(t) = \frac{k}{\varepsilon}(1 + \beta \log. t') \tag{4a}$$

$$\text{Recovery} \qquad l(t) = \frac{k}{\varepsilon}\beta \log. \frac{t + t'}{t} \tag{5a}$$

$$\text{Relaxation} \qquad k(t) = \varepsilon l(1 - \beta \log. t) \tag{6a}$$

An estimation of the after-effect constant is difficult because of the fact that the modulus of elasticity, i.e. the initial extension in the flow curves, is unknown. Similarly in the relaxation curves, the load which would produce an elastic extension equal to the constant extension held throughout the experiment, is unknown, since the filament has flowed slightly before the first reading. It is therefore necessary to apply the equations for flow, recovery, and relaxation to a difference in the conditions between the times t_1 and t_2, thus-

$$\text{Relaxation difference} \quad \frac{k_1 - k_2}{\varepsilon l} = \beta \log. \frac{t_2}{t_1} \tag{12}$$

$$\text{Flow difference} \quad \frac{\varepsilon(l_2 - l_1)}{k} = \beta \log. \frac{t_2}{t_1} \tag{13}$$

$$\text{Recovery difference} \quad \frac{\varepsilon(l_2 - l_1)}{k} = \beta \log. \frac{t_1}{t_2} \tag{14}$$

The actual starting load applied is substituted for εl in the relaxation curve; the extension at the first reading, for $\frac{k}{\varepsilon}$ in the flow and contraction curves. The relative error in β is then equal to the relative error in the modulus of elasticity.

By substituting the value for β thus obtained, in equations (4a), (5a), and (6a), a correction for k_0 or l_0 is obtained by means of which a more correct value for the modulus of elasticity may be reached. By this means the value of β is made correct to within a few per cent

The values of β are arranged in Table VI.

Table VI

Load	Flow Curve	Recovery Curve	Experiment No
0·95 grams	0·064	0·060	61
0·95 ,,	0·047		62
1·06 ,,	0·044	0·053	56
1·86 ,,	0·098	0·111	64

Starting Load	Relaxation Curve	Experiment No
2·09 grams	0·087	52
3·12 ,,	0·100	57
3·20 ,,	0·091	58

For the flow curves alone β appears to be dependent upon the load, as was indicated by the curves themselves (Fig. 8). The β values in the recovery curves show the same trend as the β values in the flow curves. This is another indication that the spread observed in the various experiments is essentially due to the material itself.

For the individual experiments, therefore, the Boltzmann theory provides a conversion of the flow and relaxation curves into one another.

The β value calculated from the relaxation curves made under 2 and 3 grams starting loads is in approximate agreement with that calculated from the flow curves under 2 grams.

The points in Fig. 4 can now be corrected as indicated by the crosses (Curve II). The modulus of elasticity is only slightly altered, the corrected curve is also a straight line.

To summarize the discussion of the experimental results, it may be stated that the Boltzmann after-effect theory provides a useful approximation to the actual behaviour of rayon.

Although it is worthy of note that the deviations from the theory are more marked in the flow curves than in the relaxation curves, it is possible that a further investigation of the relaxation phenomena might also show an alteration in the mechanical properties.

The influence of temperature and of degree of swelling on the flow is such that the general form of the curve remains the same; only the rate of change is altered. This means that Becker's function for the distribution of plasticity is approximately independent of temperature and degree of swelling. In this respect the flow curves differ markedly from stress-strain curves of viscose[9] whose course is qualitatively as well as quantitatively altered by swelling. The reason for this independence of the plastic homogeneity of swelling and temperature is not clear, since a change in the distribution of plasticity, due to these influences, might more reasonably be expected.

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12—A STUDY OF COMPARATIVE RESULTS FOR LEA, SINGLE THREAD, AND BALLISTIC TESTS ON YARNS FROM STANDARD INDIAN COTTONS

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SUMMARY

It is pointed out that while the lea test suffers from the disadvantages that in practice yarn is seldom treated in lea or hank form, and that the test-results are difficult to interpret, it has three great advantages in (1) being popular, (2) involving a comparatively small sampling error, and (3) providing the specimens required for the determination of counts. The single-thread test suffers from none of the objections to the lea test, and, moreover, it yields a result for the extension of the yarn; but, as ordinarily carried out, it involves a much greater sampling error. The advantages claimed for the recently developed ballistic test are also examined, reference being made more particularly to the work of Lester, and Midgley and Peirce. In the comparison of the lea and single-thread tests reference is made to the work of Bowman, Gégauft, Corser and Turner, G. R. Smith, and W. J. Hall.

The testing of the standard Indian cottons has provided an opportunity of comparing the three methods of testing on an extensive scale. Results are available for 22 cottons of 1926–27, 1927–28, 1928–29, and 1929–30. The total number of tests made was 20,700 for lea strength and counts, 20,700 for ballistic work and counts, and 82,800 for single thread strength and counts. The ballistic tests have been made in two series, one with the ends of the lea free to move round the fixing rods, and the other with the ends fixed.

The results for the various tests are discussed in the form of their ratios to one another. The ratio of lea count-strength product to ballistic count-work product varied from 0·32 for 6/10's to 0·51 for 20/40's when the lea ends were free to move; and from 0·41 for 6/10's to 0·63 for 20/40's when the ends were fixed. These differences for various counts are due chiefly to differences in yarn-extension, although the degree of the twist also appears to be a factor of importance. The higher counts give slightly lower values for the ratio of lea count-strength product to single-thread count-strength product, but no general rule is deducible. The ratio of the single-thread count-work product to the ballistic count-work product is also variable but is distinctly higher when the lea ends are fixed in the ballistic tests, under which conditions it ranges from 0·87 for 6/10's to 0·79 for 20/40's. The irregularity of the results is decidedly less for the ballistic test than for the lea test, but much greater for both than for the single-thread test, when due allowance is made for the difference in the numbers of threads tested; the greater regularity of the results obtained by the ballistic test is somewhat discounted by the fact that they are much more affected by changes of humidity.

The three methods of testing are also compared by placing the staple cottons of each season in their order of rank according to each test. It is found that all the tests agree fairly well together, but whereas the differences between the lea strength and single thread strength results are negligible, the differences between the ballistic strength results and those of the other tests are more serious.

The conclusion is finally reached that though there is not sufficient evidence available at present to justify a recommendation that the lea test should be discarded in favour of the ballistic test, yet the latter is a good test of yarn and worthy of a much more extended examination.

I—INTRODUCTION

The lea test has recently been subjected to a great deal of criticism. There is in fact no denying that it suffers from a number of defects. There are two chief objections to it; first, that in practice yarn is scarcely ever

treated in the form of a lea or hank, the only noteworthy exceptions being hank sizing, hank bleaching, hank mercerising, and hank dyeing. In other practical operations—winding, warping, beaming, slasher sizing, and weaving—the yarns are so stressed and strained that the breakage of a single thread leaves the other threads practically unaffected. But in the lea test one continuous length of yarn is being tested and the breakage of a single thread affects the portions of yarn near the place of breaking, so that when the lea is broken in only a few places it cannot withstand any further increase of load. Hence the lea strength test cannot be a complete guide to the behaviour of the yarn in the practical processes. The second objection to the test is the difficulty of interpreting the results when obtained; although the lea test is commonly regarded as a strength test, pure and simple, the results of which provide a measure of the quality of the yarn, yet they also depend upon the extensibility and the surface friction of the yarn.

The two disadvantages of the lea test may be offset by its three great advantages, viz. (1) its universal popularity; (2) the comparatively small sampling error which its use involves; and (3) the counts are readily determined on the same test-specimens. The lea test is practically the only test for strength used in mills. Its popularity may be accounted for by the fact that it is both simple and speedy; moreover, most of the persons engaged in the industry are familiar with the test, and possess established conceptions of what the test-results should be for a yarn having a given count and twist. It follows, therefore, that the lea test is unlikely to lose its popularity or be discarded in favour of some new test unless this can show undoubted advantages; a test which appears to be only slightly superior to the lea test is hardly likely to find a ready adoption. The second advantage enjoyed by the lea test needs but little explanation; an ordinary spinning mill produces a large amount of yarn even in a short time, e.g. a mill of 100,000 ring spindles could produce daily 6,000,000 leas of 20's counts; it is clearly desirable that the amount of yarn tested shall not be so small a fraction of the whole that it is likely to be completely unrepresentative. It cannot of course be expected that a mill will test any large proportion of its production, because if the fraction tested were at all large it would mean less yarn (and more waste) would be available for sale and additional expense would also be incurred in maintaining a large testing staff. Ordinarily not more than one lea from one bobbin per side of each ring frame would be subjected to test each day in the mill; in 20's counts this represents about one lea in 9,000 spun, so that even with the lea test only a small portion of the yarn is actually subjected to test. The third advantage of the lea test is that the counts of yarn can be determined on the test-specimens after they have been broken; this obviously saves the time required in reeling a second set of specimens, and, furthermore, ensures that the strength and counts results pertain to the same set of specimens, and avoids an additional sampling error that might otherwise arise.

As previously mentioned, the lea test is practically the only strength test used in mills; in textile laboratories, however, this test is often supplemented by a single thread test. The single thread test suffers from neither of the objections which may be urged against the lea test; in addition, it yields a figure for the extension of the yarn. But it does not have the same advantages as the lea test. One lea test is made on 120 yards length of yarn, whereas a single thread test is made on a length of one or two feet, so that if the same amount of material were to be used in both kinds of test it would be necessary to make from 360–180 times as many single thread tests

as lea tests. The time taken in making so many single thread tests is, generally speaking, prohibitive, and hence it is usual to subject a much smaller length of yarn to single thread tests than to lea tests, with a corresponding possible increase in the sampling error. At the Technological Laboratory a compromise is made, and the number of single thread tests (made on 1-ft. lengths) is four times as great as the number of lea tests. But to make 200 tests on the ordinary single thread testing machine takes twice as long as 50 lea tests, and even so, 90 times as much yarn is tested in the lea tests as in the single thread tests. Hence, if it became mill practice to use the single thread test instead of the lea test, twice as large a staff would be required to carry out four times as many tests, and the proportion of the production tested would be reduced from one part in 9,000 to one part in 810,000. The only way to overcome this difficulty would be to use an automatic single thread tester, such as the Moscrop testing machine; this would enable the same staff to cope with about half the amount of material tested in the lea test; but the counts would have to be determined separately, and no result would be obtained for the yarn-extension.

Developments in the last few years have led to the introduction of a new form of test known as the ballistic test. The ballistic test was strongly recommended for yarns and fabrics by Lester[1a] as long ago as 1910. The advantages claimed for the ballistic test by Lester are that it may be applied with greater rapidity than other tests; that the method is scientific and that the results have a scientific value as compared with the lea strength test; and that[1b] "since the method gives proper importance to the elasticity of the sample, it indicates better than existing methods, the true strength of the yarn, the 'toughness,' and the actual working quality." The investigations of Midgley and Peirce[2a] have led them to agree with Lester that the ballistic test offers many advantages; and having pointed out that a yarn usually breaks in practice as the result of a jerk, they continue[2b]—"Fortunately the work absorbed in a rapid break is capable of convenient measurement by the ballistic method. This test is being used increasingly on metals and other materials, but in no field are its advantages so decided as in textile testing." They have accordingly designed a new ballistic tester, which is supplied by Messrs. Goodbrand, and claim that "the tester has been developed with the object of providing a test as convenient as those in vogue for commercial purposes, while giving a result of exact and scientific meaning. It is introduced on the grounds that the quantity measured is the most significant single measure of yarn strength, but its use might equally be justified from the viewpoint of testing routine."

Midgley and Peirce[2c] further claim that the ballistic tester is suitable not only for yarns but also for tapes and strips of duck. Its utility for fabrics appears doubtful, however, in view of the reasons advanced by Morton and Turner,[3] but the case which is made out for its use as a yarn tester certainly appears to be a strong one. As a consequence, some comparative experiments have been carried out at the Technological Laboratory on the standard Indian cottons forming the subject of "Technological Reports on Standard Indian Cottons, 1930." Every season each of these standard cottons is spun in duplicate lots in three different counts of yarns; each type of yarn is then subjected to 50 lea tests and 200 single thread tests. The cottons of the seasons 1926–27, 1927–28, 1928–29, 1929–30 were also subjected to ballistic tests, 50 such tests being made on each type of yarn, though the 1928–30

tests were carried out in a different manner from the 1926-28 tests, as explained on pages T203-T204. The results obtained therefore provide a means of comparing in a very extensive manner the three tests, viz. lea test, single thread test, and ballistic test.

II—PREVIOUS WORK

Reference has already been made to the work of Lester, and of Midgley and Peirce, on the ballistic test. Various workers have made comparisons of lea and single thread tests. Midgley and Peirce[24] have introduced the convenient expression "lea ratio" to denote the ratio between lea strength (calculated as per single thread) and the actual single thread strength; in order to express the lea ratio as a percentage, the single thread strength is taken as 100.

Bowman[4] gives a number of results for single and twofold yarns, viz. American 20's single broke at 12 oz. single thread, and at 79 lb. lea (=7·9 oz. single thread), giving a lea ratio of 67 per cent. A single Egyptian breaking at 7 oz. single thread, and 54 lb. lea, gave a lea ratio of 78 per cent. Twofold yarns gave even smaller lea ratios; thus twofold 40's Egyptian twiner yarn breaking at 21 oz. single thread, and twofold 60's Egyptian twiner breaking at 14 oz. single thread, each gave a lea ratio of 50 per cent.

Gégauff[22] made experiments on this subject and noted that strong leas gave lower lea ratios than weak ones. In some results published by Corser and Turner[5] it was found that the lea ratios of 60's single grey Sakel yarn were 54, 72, and 64% for yarns spun with twist constants of 2, 3, and 4 respectively. The results obtained for twofold yarns were very different from those of Bowman. As shown in the table below, the lea ratios ranged from 71% for the twofold yarn spun with a single twist-constant 4 and twofold twist-constant 3, to 78% for the yarn spun with single twist-constant 2 and doubled with twist-constant 3. Among the mercerised twofold yarns the lea ratio varied from 60% to 73 per cent. In one or two cases yarns which appeared stronger by the lea test appeared weaker by the single thread test.

Table I

Lea Ratios for 2/60's Sakel Spun with Different Twists

Singles twist constant.	2	2	2	3	3	3	4	4	4
Doubling twist constant	3	4·5	5·6	3	4·5	5·6	3	4·5	5·6
Grey	78	77	72	74	71	73	71	74	71
Mercerised (M1)	73	68	67	68	65	65	68	66	60
Mercerised (M2)	73	70	66	68	64	68	64	63	62

M1 = mercerised under tension
M2 = mercerised without tension but extended to original length before removal of alkali

The interest of these figures lies in the fact that they have been obtained for the same cotton spun and doubled in many different degrees of hardness; they relate also to the several yarns in the grey state and after mercerisation by two different methods. When it is borne in mind that for each grey yarn only 10 lea tests and 200 single thread tests were made, and for each mercerised yarn only 8 lea tests and 100 single thread tests, it is clear that these figures are subject to a considerable sampling error, and that it can by no means be regarded as certain that the differences in the lea ratios are real and not due in part at least to sampling error.

It has long been generally recognised that the lea test suffers from a number of defects; G. R. Smith[6] criticises the lea test as follows—

"The results obtained by the lea test cannot be said to have much value, because we do not know how to express the stretch we partly and roughly measure, and we do not know how the hank broke down. . . Some persons consider the hank broken when the first two or three threads break, others when many threads break, while others pull the hank until it ceases to register a further breaking load. . . This method of testing does not give the least strength of the thread in the hank, neither does it give the average strength of the yarn or maximum strength of the yarn. It gives a number which indicates that other yarns which have yielded this number have been passable. Custom has sanctioned this method of testing, with all its faults, and fostered an erroneous notion which is deeply rooted, viz. that the lea test is an average strength test, when it is nothing of the kind. It will die slowly, because the men in commerce who talk about the strength and 'elasticity' (stretch) of yarns have grown up with it, and the numbers it gives conveys to their mind that it is or is not strong enough, and in all probability it will only be self-preservation which will cause them to take to another system of testing."

In view of these objections Smith prefers the single thread test, which he claims to have none of the disadvantages to which he refers. He overlooks, however, the previously-mentioned drawbacks from which the single thread test suffers.

An entirely contrary view is taken by W. J. Hall[7] who, as a result of tests on woollen, worsted, and cotton yarns, defends the lea test against the single thread test, and considers that "for the ballistic test a more extensive research appears to be necessary for yarns, particularly if such a test is to replace the hank test." From his experiments Hall concludes that—
"although the strength of the single thread cannot be deduced from the results of the hank tests, yet the hank test will grade a series of yarns in approximately the same quantitative order as the single thread test, and that since most tests are comparative rather than absolute, the hank test is thus proved to be of considerable value, particularly when it is remembered that generally single thread testing is unreliable on account of the insignificant amount of material tested, and impracticable for general use if enough tests are carried out to give truly representative results . . . the hank is less suitable for comparing yarns of entirely different character, e.g. woollen, worsted, or cotton, and should not be used for this purpose without confirmation by other means."

III—THE PRESENT TESTS

Object—As previously indicated, the present tests were designed to determine how far the ballistic test is a measure of the strength and true quality of the yarn, and to make a comparative study of it and the other strength tests in vogue, viz. lea and single thread tests.

Cottons—The tests were carried out on the standard Indian cottons of the four seasons 1926–30; full details of these cottons are given in "Technological Reports on Standard Indian Cottons, 1930"; the cottons display a wide range of district of growth, botanical species, fibre-properties, and highest suitable counts as will be clear from the summary of these particulars given in Table II, page T202.

Table II

The Standard Indian Cottons

No	Cotton	Province	Botanical Species	Fibre-length (inch)	Fibre-weight per inch (millionth of an ounce)	Fibre-strength (ounce)	Highest standard Warp Counts
1	Dharwar 1	Bombay	*Gossypium herbaceum*	0·87	0·182	0·129	34
2	Gadag 1	,,	*G. hirsutum*	0·82	0·162	0·141	26
3	1027 A L F.	,,	*G. herbaceum*	0·96	0·204	0·165	32
4	Wagad 4	,,	,, ,	0·84	0·216	0·138	16
5	Wagad 8	,,	,, ,,	0·80	0·239	0·144	15
6	P.A. 4F	Punjab	*G. hirsutum*	0·81	0·179	0·167	20
7	P.A. 285F	,,	, ,,	0·92	0·158	0·162	42
8	P.A. 289F	,,	,, ,,	1·00	0·147	0·148	42
9	Mollisoni	,,	*G indicum*	0·69	0·298	0·167	8
10	Aligarh A 19	United Provinces	*G neglectum roseum*	0·68	0·314	0·211	7
11	Cawnpore K 22	,, ,,	Hybrid (*neglectum roseum* × *arboreum*	0·70	0·229	0·171	11
12	J.N. 1	,, ,,	*G. neglectum Malvense*	0·75	0·237	0·185	12
13	C.A. 9	,, ,,	*G. hirsutum*	0·87	0·174	0·168	34
14	Akola Verum	Central Provinces	*G. neglectum verum*	0·84	0·195	0·171	21
15	Nagpur Verum	,, ,,	,, ,,	0·81	0·190	0·175	21
16	Umri Bani	Hyderabad	*G. indicum*	0·81	0·172	0·171	27
17	Cambodia Co. 1	Madras	*G. hirsutum*	0·93	0·170	0·125	32
18	,, Co 2	,,	,, ,,	0·92	0·148	0·099	26
19	Nandyal 14	,,	*G. indicum*	0·91	0·187	0·236	31
20	Hagari 1	,,	*G. herbaceum*	0·84	0·207	0·140	24
21	Hagari 25	,,	,, ,,	0·90	0·188	0·132	30
22	Karunganni C7	,,	*G. indicum*	0·81	0·186	0·159	20

Procedure—The procedure followed in these tests was exactly similar to that described in "Technological Reports on Standard Indian Cottons, 1930." Each sample was passed through the lattice feeder, Crighton (twice), hopper, scutcher (three times), card, drawing (two heads), slubber, inter, rover, and spun from single hank roving in the ring frame. Duplicate lots of each cotton, each weighing 10 lb., were subjected to this treatment; but eight of the cottons of the 1926–27 season (Dharwar 1, Gadag 1, P.A. 285F, P.A. 289F, Cambodia 295, Nandyal 14, Hagari 25, and Karunganni C) were spun into four different lots, one pair at a high and one pair at a low spindle speed. Ten bobbins of roving were prepared from each lot; the ten bobbins from one lot were then placed in the creel of the ring frame and spun on spindles 1–10 while the ten bobbins from the duplicate lot were spun on spindles 73–82. A list of the more important machinery particulars will be found in "Technological Reports, 1930" (p. 9).

Testing—As previously mentioned, each of the standard cottons was spun in duplicate in 1926–27, 1927–28, 1928–29, and 1929–30, except the eight cottons of the 1926–27 season, which were spun in four different lots. Each lot was spun into three counts of yarn; ten bobbins of yarn of each count were spun from each lot. The numbers of tests made on the yarn from each bobbin were as follows—

For lea strength and counts	5
For ballistic strength and counts	5
For single thread strength and extension and counts	20

Hence each mean result given in the Appendix, Tables I–IX, represents the average of 100 tests for lea strength and counts, 100 tests for ballistic work and counts, and 400 tests for single thread strength, extension, and counts. As the total number of bobbins tested is 4,140 (77 samples; each spun in two lots; one count per lot for two samples, two counts per lot for 29 samples, three counts per lot for 37 samples, and four counts per lot for nine samples, and ten bobbins per count) it follows that the total number of tests made is 20,700 for lea strength and counts, 20,700 for ballistic work and counts, and 82,800 for single thread strength, extension, and counts.

The various yarn tests were carried out as follows—

(1) *Counts actual*—Determined on an Avery Yarn Balance by weighing each lea (or portion of lea) previously used in the lea and ballistic tests respectively; the counts of yarn in the single thread tests were determined for each bobbin by weighing together, on a torsion balance of maximum load 500 mgm., all the yarn used for the 20 tests from that bobbin.

(2) *Lea strength*—Determined in the Goodbrand Lea Tester No. 18, maximum load 150 lb., electrically driven.

(3) *Ballistic strength*—Determined on half-leas for counts equal to 20's and higher, and on quarter-leas for counts less than 20's, in the Goodbrand's Ballistic Testing Machine; in one case, Mollisoni (1926–27), one-eighth leas were used in testing. The results given in the tables are calculated for one lea by multiplying by 2, 4, or 8 according as the length used in testing is half, quarter, or one-eighth of a lea, as the work done varies directly as the number of threads used.

There was one important difference in the testing of the cottons of 1926–28 and those of 1928–30. The leas of the former were placed in the ballistic tester and the ends left free to move round the crossbars just as in the lea test; but the leas of the 1928–30 cottons were placed in the tester with a hitch knot

at each crossbar so as to prevent any such motion of the threads; with free ends not all the 160 threads break, for some begin to slip round the crossbars as soon as a few break, just as in the lea test itself—but with the ends fixed all the threads break and no slippage is possible. The free-end method permits of a great absorption of energy in extending the partially broken lea, and is therefore even more unsatisfactory than the lea test itself; the extension with the ends fixed is the true extension of the yarn, and it follows that the machine should only be used with the lea ends fixed, as recommended by Midgley and Peirce. The results of the present investigation show that although only a fraction of the 160 threads break when the ends are free, yet the work of rupture is much greater in this case than when the ends are fixed. Midgley and Peirce have shown that the work done in breaking a lea with fixed ends is double that for breaking a half lea, or four times that of a quarter-lea, as in each case the result is what would be obtained by adding the results for the individual threads tested separately; this does not hold good either for the ordinary lea test or for the ballistic test with free ends.

(4) *Single thread strength and extension*—Determined on 12-inch lengths in the Goodbrand Single Thread Tester No. 20, maximum load 16–64 oz.

The rate of traverse of the lower grip in the lea and single thread testing machines is 12 inches per minute.

The individual results of each of the various tests on each count of each cotton show considerable variation among themselves; the extent of this variation is indicated by the "irregularity," which is calculated by subtracting from the mean the average of all those results which are less than the mean and then dividing this difference by the value of the mean; the fraction thus obtained is multiplied by 100 to express the irregularity as a percentage.

The irregularity for lea and ballistic test results has been calculated in two ways. The first method is to determine the irregularity for the five tests on each bobbin and then find the average of the 20 percentage irregularities for the 20 bobbins of each count. The second method is to take together all the 50 results of one lot of one count, and to find their irregularity, and then to find the mean of the two results thus obtained for the two lots. The first method eliminates the bobbin effect, and gives the average irregularity of the strength of the yarn on a bobbin; the second method has the disadvantage of not eliminating the bobbin effect. From Table III, page 9, it may be seen that the irregularities in lea and ballistic tests are generally lower by the first method, as is to be expected with the bobbin effect eliminated.

The second method of taking all the results together has been adopted for all the single thread strength results; we realise that the irregularity would be more correct if calculated for each bobbin separately, because there may be inter-spindle effects as shown by Tippett,[8] but the second method may at least be regarded as a first approximation.

The irregularity for the single thread test results has been calculated directly from the 200 results for each yarn, and the mean taken of the two values obtained from the two lots in each case. In order to make all the figures for irregularity truly comparable, the ballistic irregularities are shown in the tables as for leas; and as the irregularity is inversely proportional to the square root of the number of threads tested, it has been necessary to apply the correction-factors $\frac{1}{\sqrt{2}}, \frac{1}{2}, \frac{1}{2\sqrt{2}}$, to the irregularities of ballistic work

Table III

Comparison of Two Methods of Determining Irregularity (%)

Cotton	Season	Counts	Lea Irregularity: Bobbins combined	Lea Irregularity: Bobbins taken separately	Ballistic Irregularity: Bobbins combined	Ballistic Irregularity: Bobbins taken separately
Dharwar 1 ...	1928–29	20's	3·5	3·3	3·1	2·9
,, ..	1929–30	,,	5·9	5·4	2·9	2·5
Jayawant ...	1929–30	,,	5·9	4·8	3·7	3·2
Gadag 1 ...	1928–29	,,	5·8	5·8	4·0	3·0
,, ...	1929–30	,,	4·5	4·5	2·7	2·1
1027 A.L.F. ...	1928–29	,,	4·2	4·2	3·4	3·0
,, .	1929–30	,,	5·0	4·1	2·6	2·7
P.A. 4F ..	1929–30	,,	10·5	9·5	4·4	3·5
P.A. 285F ...	1929–30	,,	4·2	4·3	4·3	3·9
P.A. 289F ..	1929–30	,	7·0	3·5	3·9	2·8
C.A. 9	1929–30	,,	5·3	5·0	3·0	2·6
Akola Verum ...	1929–30	,,	8·1	6·9	4·4	4·1
Nagpur Verum	1929–30	,,	8·1	7·3	4·1	3·9
Umri Bani ..	1929–30	,,	7·4	5·4	3·0	3·4
Co. 1	1928–29	,,	4·5	3·5	4·1	3·6
,, ...	1929–30	,,	5·0	4·2	4·1	3·4
Co 2	1928–29	,,	4·6	3·8	3·3	3·4
,, ...	1929–30	,,	4·6	4·0	3·3	2·9
Nandyal 14 ..	1928–29	,,	7·4	6·2	3·5	3·1
,, .	1929–30		5·9	6·6	3·4	3·2
Hagari 1 .	1928–29	,	4·9	4·7	3·7	4·0
,,	1929–30		7·1	5·2	3·2	2·8
Hagari 25 .	1928–29	,,	3·0	2·3	5·8	4·6
,, .	1929–30	,	5·5	5·5	3·5	3·4
C 7	1928–29	,,	5·7	5·7	4·3	4·2
,, ...	1929–30	,,	8·1	5·5	3·9	4·4
Mean ...		,,	5·8	5·0	3·7	3·3
Dharwar 1 ...	1928–29	30's	4·2	4·3	3·6	3·2
,, ...	1929–30	,,	7·1	6·9	3·2	2·8
Jayawant ...	1929–30	,,	7·2	6·1	2·7	2·2
Gadag 1 ...	1928–29	,,	6·3	6·3	4·1	3·4
,, ...	1929–30	,,	6·4	5·8	2·2	2·8
1027 A L.F. ...	1928–29	,,	5·5	5·4	4·5	4·3
,, ...	1929–30	,,	4·9	3·8	2·9	2·8
P.A. 285F ...	1929–30	,,	3·8	4·0	3·1	3·1
P.A. 289F ...	1929–30	,,	6·2	5·1	4·9	3·9
C.A. 9	1929–30	,,	5·8	5·6	2·1	2·3
Co. 1	1928–29	,	4·7	4·4	4·6	3·7
,, ...	1929–30	,,	4·7	3·9	2·7	2·5
Co. 2	1928–29	,,	5·1	3·6	5·0	4·9
,, ...	1929–30	,,	5·0	4·4	2·9	2·7
Nandyal 14 ...	1928–29	,,	9·5	7·5	5·0	4·4
,, ...	1929–30	,,	7·8	6·7	3·0	2·3
Hagari 25 ...	1928–29	,,	4·1	6·0	3·1	2·9
Mean ...	—	,,	5·8	5·3	3·5	3·2
P.A. 289F ...	1929–30	40's	5·9	4·5	5·4	4·7
Co. 1	1928–29	,,	5·2	3·7	4·9	4·9
,, ...	1929–30	,,	4·5	3·8	2·4	2·4
Mean ...	—	,,	5·2	4·0	4·2	4·0

determined on half, quarter, and one-eighth leas respectively. Tables I–IX (Appendix) give the actual results for each count and show the lea count-strength product, ballistic count-work product, single thread count-strength

product, single thread count-work product, and their ratios derived from these results. The single thread count-strength and count-work products have been calculated as for 27-inch lengths, this being the length of a strand in the lea or ballistic test. The strength of a 27-inch length was assumed to be the same as that of the 12-inch specimen actually used, as we have reason to believe that no correction-formula is sufficiently accurate to be worth applying in this case; the extension was assumed to increase in the same proportion as the length. The product of half the extension for a 27-inch length and the count-strength product gives the count-work product.

The effect of Humidity on the Results of the Strength Tests—The values of the relative humidity recorded in the several tests on each type of yarn are also given in Tables I–IX (Appendix). It will be observed that most of the yarns were tested between 60 and 80% R.H., and that the differences in the relative humidity prevailing during the different tests on any one yarn were quite small, so that in the discussion of the values of these ratios it is possible to ignore the effects of differences in humidity. But a few experiments were made with a view to determining to what extent the results obtained by the different tests are dependent upon the relative humidity at which the yarns have been conditioned before being tested. For this purpose parallel tests were made at three different humidities, 40, 60, and 80% respectively.

The tests were carried out in the following manner—The leas were reeled off and placed on a framework so designed that 45 leas could be suspended on it, with all the strands kept parallel without overlapping, in the same stretched condition as on their removal from the wrap reel. The yarn was conditioned at a particular humidity (40, 60, or 80%) for at least an hour before being tested. Previous weighing tests showed that the moisture-content of the yarn did not change appreciably under the conditions of these tests after half an hour's exposure at a particular humidity. In the case of the single thread tests the yarns were wound on black winding cardboards and exposed for conditioning for an hour at the particular humidity before being tested.

That the leas when being tested were at least approximately in humidity-equilibrium with the surrounding atmosphere is shown by the results of some moisture-determinations on sets of four leas of Rajpipla yarns which were weighed after being conditioned for an hour in the same manner as the leas used in strength-testing; and were then dried in a conditioning oven and the loss of weight determined. The moisture-contents were found to be—

6·75% at 40% R.H.
8·21% at 60% R.H.
9·00% at 80% R.H.

Thirty-five bobbins of 40's counts were spun of Rajpipla (1927–28) cotton for these tests. A single set of ten bobbins was used for the lea and single thread tests on four different dates, when the relative humidities were 40, 60, 80, and 60% respectively; five lea and 20 single thread tests were made successively on each bobbin at each relative humidity; five bobbins were similarly subjected to ballistic tests at each relative humidity. In a parallel series of tests, three bobbins were exhausted completely in lea tests at each humidity, and two bobbins were similarly exhausted completely in ballistic tests. All the tests were carried out as explained above, the ballistic tests being made with fixed ends. The results are given in the following tables—

Table IV

The Effect of Humidity on Lea Strength

Ten Bobbins Tested at each Humidity successively					Three Bobbins Exhausted at each Humidity				
No. of Tests	Counts Actual	Strength (lb.)	Count-strength Product	Relative Humidity (%)	No. of Tests	Counts Actual	Strength (lb.)	Count-strength Product	Relative Humidity (%)
30	38·7	32·4	1254	44	45	38·2	32·9	1257	41
30	38·3	33·3	1275	58	45	39·2	31·5	1235	60
30	38·4	33·2	1275	79	51	38·4	33·3	1279	78
26	39·7	31·9	1266	60	45	39·2	32·3	1266	61

Table V

The Effect of Humidity on Ballistic Test Results

Five Bobbins Tested at each Humidity successively					Two Bobbins Exhausted at each Humidity				
No. of Tests	Counts Actual	Work of Rupture (inch-lb.)	Count-work Product	Relative Humidity (%)	No. of Tests	Counts Actual	Work of Rupture (inch-lb.)	Count-work Product	Relative Humidity (%)
25	41·2	36·2	1491	38	37	41·0	36·8	1509	37
25	40·9	49·3	2016	60	37	39·5	51·3	2026	60
25	39·8	55·3	2201	80	37	38·8	55·2	2142	80
20	41·5	49·4	2050	59	36	39·8	51·4	2046	61

Table VI

The Effect of Humidity on Single Thread Strength

No. of Tests	Counts Actual	Strength (oz.)	Count-strength Product	Extension (in.)	Relative Humidity %
200	39·9	5·1	203	0·58	42
200	42·1	4·5	189	0·64	58
200	41·4	4·9	203	0·70	76

The results of these tests are unusual so far as they relate to the single thread and lea tests, as in these cases the effect of humidity on strength is comparatively insignificant—which is at variance with what we know from other experiments. No doubt the variation in counts is to a large extent responsible for this anomaly, which may, however, be a consequence of the material having been exposed to light at some time—though the yarn, when not being conditioned for testing, was left on the bobbins, well wrapped up, and kept in the dark in a drawer.

The ballistic tests, in contra-distinction to the lea and single thread tests, display very considerable differences in the results at the different humidities; thus the ballistic count-work product increased by 35% when the humidity rose from 40 to 60%; the increase was much less—only 7%—for the change in humidity from 60 to 80%. The number of tests is of course comparatively

small, but it cannot be doubted that the ballistic test results are much more affected by humidity than either the lea test or the single thread test results.

As some time elapsed between the making of the tests at the different humidities, it was thought that some ageing effect might have been responsible for the comparatively low results obtained by the lea and single thread tests at the higher humidities. For this reason the lea and ballistic tests were repeated at 60% relative humidity, but in both cases the results obtained were substantially the same as in the previous tests made at the same humidity, and it was accordingly concluded that the difference in the effect of humidity on the lea and ballistic tests could not be ascribed to any ageing effect.

IV—DISCUSSION OF THE RESULTS

The chief purpose of these tests is to compare the results of the different kinds of tests with one another. Midgley and Peirce state [2] that—

"expressed in inch-pounds the ballistic work of a lea is usually a fraction greater than the 'pull' in pounds, but the fraction is variable, as the latter is subject to the many disturbing factors not affecting the work. Its relation to single-thread breaking load depends not only on the extensibility and on the shape of the load-extension curve, but also on the effect of speed, which may vary according to the yarn. Roughly the results by the different tests are of the following relative order—Single-thread, 6 oz. (60 lb. per lea); Moscrop, 7·5 oz. (75 lb. per lea); lea test pull, 44 lb.; ballistic work, 55 inch-lb.; but they cannot be calculated one from the other."

Although Midgley and Peirce recognise that their figures are only rough and that it is not possible to calculate the result of one test from that of another, yet even so the figures are likely to be misleading. It must not be forgotten that the ballistic work is directly dependent upon the total extension whereas neither the single thread nor the lea strength is so dependent; and as cotton yarns differ very considerably from one another in this property of extension it follows that the relation between the results of the various tests must be correspondingly affected.

The most convenient method of comparing the different tests is to express the results in the form of ratios. In each case the effect of variation in count for a given nominal count of yarn may be eliminated by expressing the results in the form of count-strength or count-work product. As ordinarily the lea test results would be compared with the ballistic test results the ratio adopted for comparing these two tests is that of the lea count-strength product to the ballistic count-work product; the lea and single thread strength tests both give readings of tensile strength direct, and so in this case the ratio used is that of lea count-strength product to single-thread count-strength product; finally, as the single thread test gives a measure of extension as well as of strength, the work done per single thread in the single thread tests is measured by ($\frac{1}{2}\times$strength$\times$extension), assuming that the relation between strength and extension is linear; hence in comparing the single thread and ballistic tests the ratio used is that of the single thread count-work product to the ballistic count-work product.

The values for the different ratios have been tabulated separately for very low counts (6–10's), for low counts (12–18's), and for medium counts (20–40's). We will now consider the results for these different ratios.

(1) *The Ratio of Lea Count-strength Product to Ballistic Count-work Product*—Table VII summarises the results for the different counts—

Table VII

The Ratio of Lea Count-work Product to Ballistic Count-work Product

	Values of Ratio for Counts—		
	6/10's	12/18's	20/40's
Lea-ends free in ballastic test	0·32	0·45	0·51
Lea-ends fixed in ballastic test	0·41	0·52	0·63

It is clear from this table that the fixing of the ends in the ballistic test causes a lower result to be obtained for the work of rupture, thus increasing the values of the lea/ballistic ratio. Yet all the values in the table are much lower than that of Midgley and Peirce, viz. 0·80. This difference is largely due to the fact that the lower counts have considerably greater extensions than the higher counts, and this alone is responsible for an increase of the work of rupture.

We will now examine the differences within each group of counts; the results for 6–10's are too few to enable us to institute any useful comparisons; but in the 12–18's group it is noteworthy that there is a tendency for the higher counts to give a slightly higher ratio than the lower counts, though the difference is insignificant compared with the difference between this group and the very low counts. The results for the different counts in the 20–40's group are not what would be expected by analogy of low and very low counts, for the extension of 40's counts is lower on the average than that of the 30's, and of the 30's than that of the 20's, the actual mean values being 0·84 for 20's, 0·74 for 30's, and 0·69 for 40's; yet the values of the strength-ratios for 20's, 30's, and 40's counts are 0·52, 0·51, and 0·49 respectively when the ends are free, and 0·63, 0·64, and 0·61 respectively when the ends are fixed, showing that the value for the highest count is very slightly less than that for the lowest in this group. That this is a real difference appears to be shown also by the fact that if we compare the results for 20's and 30's, and also for 30's and 40's, for each cotton in each season, out of the 70 pairs of values available for comparison the higher count gives a lower value for the ratio in 51 cases and a higher value only in 14 cases, while in five cases there is no difference between them. Evidently there is some influence at work which rather more than nullifies the effect of the lower extension of the higher count. It is probable that this influence is to be found in the higher twist-constant with which the higher counts are spun, the twist-constants being 3·75 for 20's, 4 for 30's, and 4·25 for 40's. This difference in twist-constant may affect the results in two ways; first, the higher twist has a greater influence upon single thread strength than upon lea strength, and as the single thread strength increases compared with the lea strength, so will the ballistic work of rupture; and secondly the actual work of rupture in breaking the fibres and separating them is also likely to be relatively greater for the yarn spun with the higher twist-constant.

(2) *The Ratio of Lea Count-strength Product to Single Thread Count-strength Product*—That the lea strength becomes less, relatively to the single thread strength, as the counts become finer, is revealed by the results for the ratio of lea count-strength product to single thread count-strength product. The

mean values for this ratio are 0·70, 0·67, and 0·64 for 20's, 30's, and 40's respectively; hence these results lend support to the explanation already advanced for the unexpected change in the value of the ratio of lea count-strength product to ballistic count-work product for the 20–40's range. Moreover, if we compare the results for each cotton spun into 20–30's and 30–40's, we find that, out of 69 pairs, 64 give a lower and only two a higher value for higher counts, while in three cases there is no difference. Now the 40's count gives of course much weaker leas than the 30's, and the 30's than the 20's count. This result therefore indicates that the stronger leas give a higher lea/single thread ratio than the weaker leas—a result which is diametrically opposed to that of Gégauff[2a] as quoted by Midgley and Peirce. Moreover, for cotton spun into a single count with twist-constants 2, 3, and 4, the results obtained by Corser and Turner (page T200), show that the yarn of medium twist and strength has the highest lea ratio. It is evidently impossible therefore to regard as a rule capable of general application Gégauff's result that weak leas give a higher lea ratio.

(3) *The Ratio of Single Thread Count-work Product to Ballistic Count-work Product*—We may now consider the ratio of single thread to ballistic count-work product; Table VIII summarises the results for the different counts—

Table VIII

The Ratio of Single Thread to Ballistic Count-work Product

	Values of Ratio for Counts—		
	6/10's	12/18's	20/40's
Lea-ends free in ballistic test .	0·61	0·72	0·64
Lea-ends fixed in ballistic tests .	0·87	0·85	0·79

The ballistic results of the low and very low counts with free-ends are few in number and very variable, and if we disregard these, we see from Appendix, Tables I–IV and VI–VIII. that, throughout the medium counts (20–40's), an increase of counts leads to a reduction in the ratio, which has the mean values 0·86 for 20's, 0·78 for 30's, and 0·72 for 40's, with lea-ends fixed, and 0·70 for 20's 0·63 for 30's and 0·60 for 40's, with lea-ends free. This may be accounted for by the effect of the difference in twist-constant to which reference has previously been made, viz. a greater work of rupture of the hairs in the case of the harder-twisted higher counts; such work of rupture is completely ignored in the calculation of the single thread count-work product. That the effect is a real one in the 20–40's range appears to be indicated by the fact that, out of 69 pairs of values taken as before, in 61 the higher count gives a lower value and in only six does it give a higher value, while in two cases there is no difference.

When the ends are fixed by hitch knots the ratio increases quite significantly in all ranges of counts, showing thereby that the ballistic count-work product has decreased and become more nearly equal to the single thread count-work product.

THE IRREGULARITY OF THE RESULTS

It is claimed for the ballistic tester that it gives very regular results. It is easy to show, however, that under similar conditions the ballistic tester would be expected to give results having an irregularity $\sqrt{2}$ times as great

as the strength test alone, assuming that the extension and its irregularity are directly proportional to the strength and its irregularity respectively. In comparing the results in the present tests, as the ballistic tests were made on fractions of leas, whereas the lea tests were made on whole leas, the values of irregularity of ballistic strength have been corrected so as to make them truly comparable, as described on page T204. It will be observed at once from the following table that the irregularity of the ballistic test is in general greater than that of the lea test when the ends are free, but decidedly less than that of the lea test when the ends are fixed.

Table IX
Irregularities of Lea and Ballistic Test Results

Season	Test	Values of Irregularity (%) for Counts		
		20's	30's	40's
1926–28	Lea	5·4	6·3	5·8
	Ballistic (ends free)	5·4	6·6	7·3
1928–30	Lea	5·8	5·8	5·2
	Ballistic (ends fixed)	3·7	3·5	4·2

The results for the individual cottons when the ends are free show considerable variation, and putting all counts together, we find the lea test irregularity is lower in 60 and higher in 51 cases. But when the ends are fixed the irregularity is less for the ballistic than for the lea test in practically every one of the 96 cases, so that these results afford a strong confirmation of Midgley and Peirce's conclusion on this subject.

The irregularities obtained in the ballistic test may also be compared with those obtained in the single thread test. Reference to the tables will show that the differences in irregularity do not fluctuate very greatly for yarns of any one count made from different cottons. We therefore confine ourselves to the mean values of the irregularities obtained for all the cottons of 20's, 30's, and 40's counts respectively. In making the comparisons it has to be remembered that the single thread irregularities relate merely to a single thread; the values of irregularity which would be obtained for 160 threads tested together as in a lea test would therefore be diminished in the proportion $1 : \sqrt{160}$. The percentage irregularity for work done, as calculated from the single thread tests, is then given by the square root of the sum of the squares of irregularity of single thread strength and single thread extension, calculated as per lea. These calculated values for the percentage irregularity were found to be 1·09, 1·25, and 1·44%, for the 20's, 30's, and 40's counts respectively; these values are only about one-fifth of the corresponding values shown in the table above for the ballistic test with the lea-ends free, and only about one-third of those with the lea-ends fixed. It is clear therefore that the values for the irregularity of the ballistic test results are not comparable with those of the single thread test results.

Again, if we calculate the irregularities of lea strength from the irregularities of single thread strength, their values should be 0·89, 0·98, and 1·09% for 20's, 30's, and 40's respectively; these values are only about one-fifth of the actual results for lea irregularity, already given above. The discrepancies between the two series show how far removed is the lea test from being really equivalent to the testing of 160 single threads.

THE RANKING OF VARIOUS COTTONS BY DIFFERENT TESTS

We may now compare the various methods of testing by placing the different cottons in their order of rank in each season according to each method of testing. The results for the six low and very low-count cottons are comparatively divergent, and all the methods of testing rank them in the same order; the present discussion is therefore restricted to the medium-count cottons.

1926–27 *Cottons: Ballistic Tests with Free Ends*—We obtain the following order* for the 1926–27 cottons—

Cotton	Ballistic Count-work Product	Lea Count-work Product	Single-thread Count-strength Product	Single-thread Count-work Product
P.A. 289F ...	8	8	8	8
Co. 1	14	14	14	14
Gadag 1 ..	2	2	2	2
P.A. 285F ...	7	13	13	13
Nandyal 14 ..	15	15	15	7
C.A. 9	13	7	7	1
P A. 4F	6	1	1	6
Dharwar 1 ..	1	3	16	15
1027 A L F ...	3	16	6	16
Karunganni ...	17	6	17	17
Hagari 25 ..	16	17	—	—
Umri Bani ...	18	18	—	—

* The numbers in this and the following tables are merely identification numbers, the cottons shown in col. 1 having the respective identification numbers of the "ballistic count-work" column.

The ballistic tests on these cottons were made with the ends free to move on the crossbars. It will be observed that the chief difference in order between the ballistic and lea tests is the displacement of Nos. 7, 13, and 6. The lea and single thread strength orders are exactly the same. The most notable difference between the orders according to the ballistic and single thread count-work products is the great relative change in the positions of Nos. 15 and 13; these are adjacent in the ballistic test order, but No. 15 is three places lower and No. 13 two places higher according to the single thread test.

1927–28 *Cottons: Ballistic Tests with Free Ends*—For the 1927–28 cottons, also tested ballistically with free ends, the following is the order of ranking—

Cotton	Ballistic Count-work Product	Lea Count-strength Product	Single-thread Count-strength Product	Single-thread Count-work Product
P.A. 289F ...	8	8	8	2
Gadag 1 ...	2	2	2	8
Co. 1	14	14	14	7
Nandyal 14 ...	15	7	7	14
P A 285F ..	7	1	1	1
Dharwar 1 ...	1	15	15	15
C.A. 9	13	13	13	13
Karunganni ...	17	3	3	3
Umri Bani ...	18	16	17	16
Hagari 25 ...	16	17	16	18
1027 A L F. .	3	18	18	6
P.A. 4F	6	6	6	17

In this case the chief differences in the ballistic and lea orders of ranking are that Nos. 15, 17, and 18 are placed two places higher, and No. 3 three

places lower by the ballistic test. The only difference between the lea and single thread strength tests is that Nos. 16 and 17, which are adjacent in each list, change places. The order according to the single thread count-work product differs frequently from the ballistic order; the chief differences are that Nos. 17 and 15 are respectively four and two places higher by the ballistic test, and Nos. 7 and 3 are respectively two and three places lower.

If we now sum up the differences between the different tests it will be seen that all the tests agree fairly well together, although the divergences of the ballistic tests are rather greater than for either of the other two. The differences between the lea strength and single thread strength results are in fact negligible; but the same cannot be said of the results of the ballistic tests with ends free in testing.

1929–30 *Cottons: Ballistic Tests with Fixed Ends*—The tests on the 1929–30 cottons are more important because the ballistic tests were made on half leas with ends correctly fixed at the crossbars with hitch knots. The order in which the cottons are placed according to the different methods of testing is given below—

Cotton	Ballistic Count-work Product	Lea Count-strength Product	Single-thread Count-strength Product	Single-thread Count-work Product
P.A. 285F ...	5	5	6	5
P A. 289F	6	6	5	14
Nandyal 14 ...	13	13	7	2
Co. 1	11	7	13	6
Hagari 25 ...	15	11	2	11
C.A 9	7	3	10	7
1027 A.L.F ..	3	2	11	10
Hagari 1 ..	14	1	14	12
Umri Bani ..	10	12	3	13
Gadag 1 ...	2	10	1	3
Nagpur Verum ...	9	14	12	9
Dharwar 1 ...	1	15	15	1
Co. 2	12	16	9	15
Karunganni ...	16	8	16	4
Akola Verum ...	8	9	8	8
P.A. 4F	4	4	4	16

It will be observed that the ballistic test ranks Nos. 15 and 14 seven and three places higher respectively and Nos. 1 and 12 each four places lower, and No. 2 three places lower; the total of the differences in rank is 32 places. The changes in order according to the lea and single thread strength are numerous but generally small, but as only Nos. 15 and 4 remain unchanged, the total of the differences in rank amounts to 26 places. There are large changes in order between single thread and ballistic count-work products; the most notable changes are that the ballistic test ranks Nos. 15 and 13 eight and six places higher respectively and Nos. 2, 14, and 12 respectively seven, six, and five places lower; in this case the total of the differences in rank amounts to 44 places.

It is evident therefore that the lea and single thread tests agree better with one another than either of them does with the ballistic test, even when the latter is carried out with fixed lea-ends.

V—GENERAL REVIEW OF THE RESULTS, AND CONCLUSIONS

We may now review the results of these experiments on the ballistic test. The question we have to answer is—Does the evidence available prove the

ballistic test to be so superior to the lea test that the latter should be discarded in favour of it ? A negative answer must be given to this question at present. We have found that while there is a fairly good agreement between the lea and single thread tests in the order of quality they assign to a series of cottons, the order assigned by the ballistic test differs considerably in one or two cases. These differences may be due to errors of experiment or sampling, or to the fact that the ballistic test measures extension and strength combined. We cannot say that the order given by the ballistic test is the correct order, though it is a strong point in its favour that it gives more regular results than the lea test; at the same time it is a weak point of the ballistic test that the test-results are more largely affected by differences in humidity.

It may be pointed out that even in other industries where a ballistic test has attained a certain measure of popularity, it has become not the sole but rather a supplementary test, the chief place still being taken by the ordinary tensile test. We feel therefore that in the textile industries also the ballistic test may at least be regarded as a useful supplementary test; and although the fact that it measures both tension and extension combined is in some ways a useful property of the test, yet this must also be regarded as a drawback, because it leaves us uncertain whether a difference between two materials on the ballistic test is due primarily to differences in breaking tension or breaking extension. It is certainly true that a comparatively large amount of elastic extension is valuable, yet the ballistic test does not differentiate between elastic and inelastic extension, and there is no doubt that the tensile strength is also of some importance, especially when it is coupled with high inelastic extension. Moreover, once the yarn has passed through the various stages of preparation and becomes part of the finished cloth, the yarn extension becomes of less importance because it is only partially responsible for the extension of the fabric, and there is no evidence to show that the total extension of the yarn is one of the fundamental factors governing the utility of the fabric.

To sum up, we feel that the ballistic test is a good test of yarn and that it is certainly worthy of a much more extended examination. For this reason, the practice is now established at the Technological Laboratory of making ballistic tests not only on the yarns spun from the standard Indian and other cottons, but also on all yarns spun from samples supplied as representative of the commercial crop.

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Appendix: Table I

Results for 20'sA Counts—(Ballistic Tests with Lea-ends Fixed)

Sample No	Cotton	Season	Lea Tests: Counts Actual	Lea Tests: Strength (lb)	Lea Tests: Irregularity (%)	Lea Tests: Relative Humidity (%)	Single Thread Tests: Counts Actual	Single Thread Tests: Strength (oz)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Extension (inch)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Relative Humidity (%)	Ballistic Tests: Counts Actual	Ballistic Tests: Work of Rupture (inch lb)	Ballistic Tests: Irregularity (%)	Ballistic Tests: Relative Humidity (%)	Lea C S P	Ballistic C W P	Single Thread C S P	Single Thread C W P	Lea C S P / Ballistic C W P	Lea C S P / Single Thread C S P	Single Thread C W P / Ballistic C W P
497	Dharwar 1	1928–29	20.1	91.2	3.5	69	20.5	12.1	8.6	0.87	8.2	70	20.0	129.2	3.1	72	1833	2584	2480	2427	0.71	0.74	0.94
733	”	1929–30	19.8	87.5	5.9	63	20.8	11.1	10.7	0.79	8.9	61	20.0	118.3	2.9	60	1732	2366	2309	2052	0.73	0.75	0.87
734	Javawant	1929–30	19.9	90.2	5.9	62	20.3	13.4	9.8	0.75	7.1	63	20.0	122.5	3.7	63	1795	2450	2720	2295	0.73	0.66	0.94
513	Gadag 1	1928–29	20.2	71.0	5.8	69	20.9	10.3	12.0	0.75	7.5	69	20.1	116.9	4.0	70	1434	2350	2153	1817	0.61	0.67	0.77
719	”	1929–30	19.8	86.2	4.5	63	20.2	12.1	11.6	0.93	8.0	64	20.2	124.7	2.7	64	1707	2519	2444	2557	0.68	0.70	1.02
487	1027 A L F	1928–29	19.5	95.8	4.2	67	19.9	12.5	9.2	0.84	7.0	68	19.8	133.6	3.4	66	1868	2645	2487	2350	0.71	0.75	0.89
716	”	1929–30	19.4	97.1	5.0	62	20.0	11.8	11.9	0.79	7.8	62	19.8	130.1	2.6	63	1884	2576	2369	2097	0.73	0.80	0.81
659	P A 4F	1929–30	19.6	53.6	10.5	60	20.2	8.9	13.6	0.89	8.5	63	19.8	110.7	4.4	65	1051	2192	1798	1800	0.48	0.58	0.82
688	P A 285F	1929–30	19.4	108.7	4.2	66	20.0	13.7	10.2	0.87	7.3	64	19.6	159.9	4.3	65	2109	3134	2740	2682	0.67	0.77	0.86
660	P A 289F	1929–30	19.3	109.2	7.0	67	19.7	14.2	9.2	0.81	8.8	67	19.5	156.0	3.9	69	2107	3042	2797	2549	0.69	0.75	0.84
689	C A 9	1929–30	19.6	94.9	5.3	66	20.2	13.3	11.6	0.82	9.1	65	19.8	130.2	3.0	66	1860	2578	2687	2479	0.72	0.69	0.96
618	Akola Verum	1929–30	19.7	60.2	8.1	66	20.4	9.0	13.4	0.78	10.1	64	20.0	116.8	4.4	65	1186	2336	1836	1611	0.51	0.65	0.69
628	Nagpur Verum	1929–30	20.0	59.1	8.1	72	20.6	10.0	18.8	0.89	9.3	73	20.1	124.2	4.1	66	1182	2496	2060	2062	0.47	0.57	0.83
635	Umri Bani	1929–30	19.5	77.9	7.4	71	20.0	11.9	12.6	0.92	7.0	70	19.6	126.6	3.0	63	1519	2520	2380	2463	0.60	0.64	0.98
496	Cambodia Co 1	1928–29	19.5	88.5	4.5	72	19.7	12.0	8.7	0.96	7.1	73	19.6	136.8	4.1	70	1726	2681	2364	2553	0.64	0.73	0.[illegible]5
735	” ”	1929–30	19.9	87.4	5.0	61	20.3	11.7	8.5	0.93	7.3	63	19.9	138.5	4.1	66	1739	2756	2375	2485	0.63	0.73	0.90
505	Cambodia Co 2	1928–29	19.4	75.3	4.6	72	20.3	9.6	9.2	0.81	8.5	72	19.8	110.5	3.3	68	1461	2188	1949	1776	0.67	0.75	0.81
706	”	1929–30	20.1	78.9	4.6	64	20.7	10.5	9.6	0.95	6.6	67	20.1	122.6	3.3	68	1586	2464	2173	2322	0.64	0.73	0.94
506	Nandval 14	1928–29	20.2	79.7	7.4	71	20.9	11.5	13.[illegible]	0.83	7.2	68	20.5	142.3	3.5	70	1610	2917	2403	2244	0.55	0.67	0.77
726	”	1929–30	20.0	90.1	5.9	63	20.2	12.7	12.9	0.80	8.3	63	20.2	140.4	3.4	62	1802	2836	2565	2308	0.64	0.70	0.81
507	Hagari 1	1928–29	19.6	66.7	4.9	66	20.1	10.1	13.2	0.84	7.3	70	20.0	110.4	3.7	71	1307	2208	2030	1918	0.59	0.64	0.87
736	”	1929–30	19.4	81.0	7.1	68	20.1	11.8	9.8	0.96	7.8	63	19.7	130.2	3.2	66	1571	2565	2372	2562	0.61	0.66	1.00
508	Hagari 25	1928–29	19.3	93.5	3.0	69	20.0	11.8	10.5	0.88	7.9	72	20.2	130.7	5.8	70	1804	2640	2360	2336	0.68	0.76	0.88
737	”	1929–30	19.3	75.1	5.5	66	20.1	10.4	10.0	0.86	6.8	66	19.8	139.0	3.5	65	1449	2752	2090	2032	0.53	0.69	0.74
510	Karunganni C7	1928–29	19.4	56.7	5.7	70	19.6	9.7	11.8	0.79	10.0	71	19.6	107.6	4.3	67	1100	2109	1901	1690	0.52	0.58	0.80
717	” ”	1929–30	19.3	67.2	8.1	63	20.5	9.6	16.4	0.68	11.4	62	19.8	118.8	3.9	64	1297	2352	1968	1505	0.55	0.66	0.64
	Mean (26)	—	19.7	81.6	5.8	6[illegible]	20.2	11.4	11.4	0.85	8.1	67	19.9	128.1	3.7	66	1605	2548	2300	2191	0.63	0.69	0.86

Note—C S P = Count strength product, C W P — Count work product.

Appendix: Table II
Results for 20'sB Counts—(Ballistic Tests with Lea-ends Fixed)

Sample No.	Cotton	Season	Lea Tests: Counts Actual	Lea Tests: Strength (lb.)	Lea Tests: Irregularity (%)	Lea Tests: Relative Humidity (%)	Single Thread Tests: Counts Actual	Single Thread Tests: Strength (oz.)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Extension (inch)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Relative Humidity (%)	Ballistic Tests: Counts Actual	Ballistic Tests: Work of Rupture (inch-lb.)	Ballistic Tests: Irregularity (%)	Ballistic Tests: Relative Humidity (%)	Lea C.S.P.	Ballistic C.W.P.	Single Thread C.S.P.	Single Thread C.W.P.	Lea C.S.P. ÷ Ballistic C.W.P.	Lea C.S.P. ÷ Single Thread C.S.P.	Single Thread C.W.P. ÷ Ballistic C.W.P.
733	Dharwar 1	1929–30	19 6	93·4	3·5	61	20·1	12·4	10·6	0·82	7·2	61	19·9	124·3	3·5	63	1831	2473	2629	2425	0·74	0·70	0·98
734	Jayawant ..	1929–30	19·9	99·8	4·4	64	20·7	14·1	10·1	0·77	7·1	63	20·2	126·3	3·2	63	1986	2551	2919	2529	0·78	0·68	0·99
719	Gadag 1 .	1929–30	20·0	90·6	3·9	61	20·7	12·7	8·6	0·93	8·4	62	20·0	132·5	3·0	63	1812	2650	2629	2751	0·68	0·69	1·04
716	1027 A.L.F.	1929–30	19·7	99·0	4·1	64	20·0	12·6	8·5	0·79	8·6	63	19·8	129·4	3·7	62	1950	2562	2520	2240	0·76	0·77	0·87
659	P.A. 4F ...	1929–30	19·3	69·2	5·8	66	20·2	9·9	10·6	0·94	9·7	67	19·6	117·0	4·3	63	1335	2293	2000	2115	0·58	0·67	0·92
660	P.A 289F	1929–30	20·0	106·4	5·2	67	20·4	14·0	9·5	0·80	8·5	65	20·1	151·8	4·1	68	2128	3051	2856	2570	0·70	0·75	0·84
618	Akola Verum .	1929–30	20·0	69·9	5·6	63	20·4	10·3	11·7	0·82	8·6	64	20·2	120·6	3·9	66	1398	2436	2101	1938	0·57	0·67	0·80
628	Nagpur Verum .	1929–30	19·7	72·7	6·9	66	20·0	11·5	12·1	0·88	8·5	66	19·9	128·2	3·6	65	1432	2551	2300	2277	0·56	0·62	0·89
635	Umri Bani	1929–30	19·8	82·0	5·3	66	20·5	11·9	12·5	0·86	6 9	64	19 5	132·6	3·3	69	1624	2586	2439	2360	0·63	0·67	0·91
735	Cambodia Co. 1 ...	1929–30	19·5	95·0	4·0	65	20·2	12·4	8·4	0·93	7·3	63	19·6	151·6	4·0	66	1852	2971	2505	2621	0·62	0·74	0·88
706	Cambodia Co. 2 ...	1929–30	19·8	83·8	4·0	63	20·1	11·2	8·6	0·97	6·4	64	20·0	128·0	3·3	68	1659	2560	2251	2456	0·65	0·74	0·96
726	Nandyal 14	1929–30	19 8	105·5	4·9	63	20·6	13·3	9·5	0·80	7·0	63	20·0	147·6	4·5	60	2089	2952	2740	2466	0·78	0·76	0·84
507	Hagari 1	1928–29	19·4	79·8	5·6	68	19·8	11·2	8·0	0·86	6·4	69	19·7	120·3	3·6	72	1548	2370	2218	2146	0·65	0·70	0·91
736	„	1929–30	19·5	86·5	4·4	67	20·0	12·8	9·6	0·99	6·7	67	19·8	134·5	3·6	66	1687	2663	2560	2851	0·63	0·66	1·07
737	Hagari 25	1929–30	19·6	77·9	5·1	67	20·8	10·3	11·7	0·83	8·6	66	20·0	121·2	3·5	65	1527	2424	2142	2000	0·63	0·71	0·83
510	Karunganni C7 ...	1928–29	19·4	68·9	6·2	68	20·0	10·7	13·5	0·81	10·4	70	19·7	118·8	4·5	74	1337	2340	2140	1950	0·57	0·62	0·88
717	„ ...	1929–30	19·6	77·2	6·9	61	20·0	11·1	10·1	0·69	9·9	62	19·6	126·9	3·5	63	1513	2487	2220	1723	0·61	0·68	0·69
	Mean (17)	—	19·7	85·7	5 0	65	20·3	11·9	10·2	0·85	8·0	65	19·9	130·1	3·7	66	1689	2584	2422	2319	0·66	0·70	0·90

Note—C.S.P.=Count-strength product; C.W.P.=Count-work product.

Appendix: Table III
Results for 30's Counts—(Ballistic Tests with Lea-ends Fixed)

Sample No	Cotton	Season	Lea Tests: Counts Actual	Lea Tests: Strength (lb)	Lea Tests: Irregularity (%)	Lea Tests: Relative Humidity (%)	Single Thread Tests: Counts Actual	Single Thread Tests: Strength (oz)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Extension (inch)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Relative Humidity (%)	Ballistic Tests: Counts Actual	Ballistic Tests: Work of Rupture (inch lb)	Ballistic Tests: Irregularity (%)	Ballistic Tests: Relative Humidity (%)	Lea C S P	Ballistic C W P	Single Thread C S P	Single Thread C W P	Lea C S P / Ballistic C W P	Lea C S P / Single Thread C S P	Single Thread C W P / Ballistic C W P
497	Dharwar 1	1928–29	30.0	53.3	4.2	68	30.5	7.6	13.6	0.78	10.7	70	29.9	72.3	3.6	71	1599	2162	2318	2034	0.74	0.69	0.94
733		1929–30	29.9	48.1	7.1	62	30.6	7.0	11.9	0.66	12.9	63	29.7	80.4	3.2	63	1438	2388	2142	1590	0.60	0.67	0.67
734	Jayawant	1929–30	29.7	52.4	7.2	63	29.9	8.8	10.5	0.67	9.5	64	29.6	84.5	2.7	62	1556	2501	2631	1983	0.62	0.59	0.79
513	Gadag 1	1928–29	29.4	45.7	6.3	69	30.6	6.6	14.1	0.68	12.1	70	28.8	75.6	4.1	78	1344	2177	2020	1545	0.62	0.67	0.71
719		1929–30	30.0	50.4	6.4	63	31.2	7.8	12.6	0.80	9.5	61	29.9	84.4	2.2	63	1512	2523	2434	2191	0.60	0.62	0.87
487	1027 A L F	1928–29	30.4	50.9	5.5	66	30.9	7.2	12.1	0.67	11.5	65	30.7	68.0	4.5	65	1547	2088	2225	1677	0.74	0.70	0.80
716	,,	1929–30	29.3	54.1	4.9	62	29.8	7.3	11.5	0.68	12.7	64	29.4	85.8	2.9	62	1585	2522	2175	1664	0.63	0.73	0.66
688	P A 285F	1929–30	29.9	63.2	3.8	66	30.2	8.7	11.4	0.77	8.1	66	30.2	94.4	3.1	67	1890	2851	2627	2276	0.66	0.72	0.80
660	P A 289F	1929–30	28.9	63.3	6.2	64	29.4	9.0	12.2	0.71	10.8	67	29.2	88.6	4.9	67	1829	2587	2646	2113	0.71	0.69	0.82
689	C A 9	1929–30	29.4	57.5	5.9	64	30.4	8.5	12.8	0.72	8.5	66	29.7	86.4	2.1	64	1690	2566	2584	2093	0.66	0.65	0.82
496	Cambodia Co 1	1928–29	29.6	50.6	4	68	30.5	7.2	11.4	0.82	8.2	69	29.9	75.2	4.6	68	1498	2248	2196	2026	0.67	0.68	0.90
735	,, ,,	1929–30	29.4	54.0	4	66	29.7	7.5	11.5	0.81	8.1	64	29.7	90.6	2.7	67	1588	2691	2227	2029	0.59	0.71	0.75
505	Cambodia Co 2	1928–29	29.5	43.5	[illegible]	68	30.4	5.8	11.7	0.68	10.6	67	29.8	63.0	5.0	69	1283	1877	1763	1349	0.68	0.73	0.72
706	,, ,,	1929–30	29.7	46.5	5.0	65	31.2	6.3	11.5	0.84	7.8	66	29.8	80.8	2.9	62	1381	2408	1966	1858	0.57	0.70	0.77
506	Nandyal 14	1928–29	29.9	49.4	9.5	67	30.4	8.2	12.3	0.75	9	64	30.6	80.6	5.0	70	1477	2466	2493	2103	0.60	0.59	0.85
726	,,	1929–30	29.7	55.2	7.8	63	30.5	7.8	12.1	0.65	11.6	62	29.7	94.3	3.0	65	1639	2801	2379	1740	0.58	0.69	0.62
508	Hagari 25	1929–29	28.8	52.9	4.1	68	30.1	7.3	12.8	0.74	8.9	67	29.4	77.0	3.1	70	1523	2264	2197	1829	0.67	0.69	0.81
	Mean (17)	—	29.6	52.3	5.8	65	30.4	7.6	12.1	0.73	10.0	66	29.8	81.3	3.5	67	1552	2419	2295	1888	0.64	0.68	0.78

Note—C S P = Count-strength product C.W P = Count work product

Appendix: Table IV
Results for 34's and 40's Counts—(Ballistic Tests with Lea-ends Fixed)

Sample No.	Cotton	Season	Lea Tests				Single Thread Tests						Ballistic Tests				Lea C.S.P.	Ballistic C.W.P.	Single Thread C.S.P.	Single Thread C.W.P.	Lea C.S.P. / Ballistic C.W.P.	Lea C.S.P. – Single Thread C.S.P.	Single Thread C.W.P. — Ballistic C.W.P.
			Counts Actual	Strength (lb.)	Irregularity (%)	Relative Humidity (%)	Counts Actual	Strength (oz.)	Irregularity (%)	Extension (inch)	Irregularity (%)	Relative Humidity (%)	Counts Actual	Work of Rupture (inch-lb.)	Irregularity (%)	Relative Humidity (%)							
	34's Counts																						
497	Dharwar 1	1928–29	33·9	42·8	5·7	66	34·4	6·2	13·5	0·75	11·6	65	34·0	58·3	4·0	73	1451	1982	2133	1800	0·73	0·68	0·91
733	,, ...	1929–30	33·3	40·1	5·5	61	33·8	6·0	13·9	0·65	14·1	62	32·9	73·8	2·9	66	1335	2428	2028	1483	0·55	0·66	0·61
734	Jayawant	1929–30	34·2	40·4	8·1	63	35·2	6·9	12·3	0·60	11·2	62	34·3	72·1	3·2	65	1382	2473	2429	1640	0·56	0·57	0·66
487	1027 A.L.F.	1928–29	34·0	42·8	5·2	67	33·6	6·4	11·7	0·68	12·1	67	33·7	59·2	3·6	68	1455	1995	2150	1645	0·73	0·68	0·82
716	,, ...	1929–30	33·3	44·9	6·1	65	34·4	5·9	14·1	0·59	16·7	63	32·9	78·0	2·9	62	1495	2526	2030	1347	0·58	0·74	0·52
688	P.A. 285F ...	1929–30	33·7	52·2	5·1	66	34·7	7·1	12·9	0·70	9·4	65	34·3	84·7	3·7	67	1759	2905	2464	1940	0·61	0·71	0·67
689	C.A. 9	1929–30	33·8	45·0	7·3	65	34·3	7·1	14·2	0·66	12·1	64	34·5	75·7	3·0	68	1521	2612	2435	1808	0·58	0·62	0·69
505	Cambodia Co. 2	1928–29	33·5	35·9	4·6	69	34·4	4·9	12·6	0·61	11·8	68	33·8	52·6	4·3	72	1203	1778	1686	1157	0·68	0·71	0·65
706	,, ,, ...	1929–30	33·6	39·2	5·1	67	34·9	5·5	11·5	0·81	8·4	68	34·0	69·6	3·3	61	1317	2366	1919	1749	0·56	0·69	0·74
506	Nandyal 14	1928–29	33·6	41·6	8·5	68	34·2	6·9	12·6	0·70	10·8	67	33·3	71·3	4·4	71	1398	2374	2360	1858	0·59	0·59	0·78
726	,,	1929–30	32·8	47·9	7·7	63	33·5	7·1	13·4	0·62	12·9	62	33·7	82·7	3·4	62	1571	2787	2378	1659	0·56	0·66	0·60
508	Hagari 25	1928–29	34·3	41·4	5·4	68	34·4	6·1	13·1	0·72	11·0	71	33·9	60·9	4·2	69	1420	2064	2098	1699	0·69	0·68	0·82
	Mean (12)	—	33·7	42·8	6·2	66	34·3	6·3	13·0	0·67	11·8	65	33·8	69·9	3·6	67	1442	2357	2176	1649	0·62	0·67	0·71
	40's Counts																						
660	P.A. 289F	1929–30	39·3	41·7	5·9	62	40·9	5·9	13·3	0·63	12·3	63	39·1	60·8	5·4	65	1639	2377	2413	1710	0·69	0·68	0·72
496	Cambodia Co. 1 ..	1928–29	40·5	31·7	5·2	69	41·1	4·9	14·1	0·72	13·4	69	39·7	50·7	4·9	72	1284	2013	2014	1631	0·64	0·64	0·81
735	,, ,, ...	1929–30	39·3	34·5	4·5	66	40·6	5·0	14·2	0·72	10·4	65	39·1	68·7	2·4	65	1356	2686	2030	1684	0·50	0·67	0·63
	Mean (3)	—	39·7	36·0	5·2	66	40·9	5·3	13·9	0·69	12·0	66	39·3	60·1	4·2	67	1426	2359	2152	1675	0·61	0·66	0·72

Note—C.S.P.=Count-strength product, C.W.P.=Count-work product.

Appendix: Table V

Results for Low and Very Low Counts—(Ballistic Tests with Lea-ends Fixed)

Sample No.	Cotton	Season	Counts Nominal	Lea Tests: Counts Actual	Lea Tests: Strength (lb.)	Lea Tests: Irregularity (%)	Lea Tests: Relative Humidity (%)	Single Thread Tests: Counts Actual	Single Thread Tests: Strength (oz.)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Extension (inch)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Relative Humidity (%)	Ballistic Tests: Counts Actual	Ballistic Tests: Work of Rupture (inch lb)	Ballistic Tests: Irregularity (%)	Ballistic Tests: Relative Humidity (%)	Lea C.S.P.	Ballistic C.W.P.	Single Thread C.S.P.	Single Thread C.W.P.	Lea C.S.P. ÷ Ballistic C.W.P.	Lea C.S.P. ÷ Single Thread C.S.P.	Single Thread C.W.P. ÷ Ballistic C.W.P.
693	A. 19	1929–30	6's	6·0	98·6	7·1	71	6·0	18·8	20·3	1·21	10·3	66	6·2	270·2	5·4	65	592	1675	1128	1535	0·35	0·52	0·92
643	Mollisoni ...	1929–30	8's	7·9	93·4	7·2	64	8·1	14·6	15·8	1·17	8·6	62	7·9	258·4	3·8	67	738	2041	1183	1557	0·36	0·62	0·76
693	A. 19	1929–30	,,	7·9	79·3	8·0	70	8·0	15·4	21·4	1·12	11·8	64	8·1	217·6	4·4	68	626	1762	1232	1552	0·35	0·51	0·88
	Mean (2) ..	—	,,	7·9	86·3	7·6	67	8·0	15·0	18·6	1·14	10·2	63	8·0	238·0	4·1	67	682	1901	1207	1554	0·35	0·56	0·82
493	Wagad 4 ...	1928–29	10's A	10·4	140·2	4·1	71	10·5	19·0	9·0	1·23	6·8	70	10·6	262·4	2·7	65	1458	2781	1995	2761	0·52	0·73	0·99
494	Wagad 8 ...	1928–29	,,	10·5	138·8	3·9	71	10·5	18·5	9·9	1·14	7·1	76	10·5	253·8	2·7	70	1457	2665	1942	2491	0·55	0·75	0·93
698	,, ..	1929–30	,,	10·1	124·9	4·4	67	10·4	16·9	12·7	1·06	8·1	67	10·1	236·6	3·0	65	1261	2390	1758	2096	0·53	0·72	0·88
648	K. 22	1929–30	,,	9·9	92·7	7·0	63	10·4	14·0	14·4	0·90	11·1	64	10·1	195·2	3·7	66	918	1971	1456	1474	0·47	0·63	0·75
690	J.N. 1 ...	1929–30	,,	10·1	91·7	7·8	66	10·4	14·8	14·8	1·04	8·8	65	10·2	215·0	2·9	69	926	2193	1539	1801	0·42	0·60	0·82
	Mean (5) ...	—	,,	10·2	117·7	5·4	68	10·4	16·6	12·2	1·07	8·4	68	10·3	232·6	3·0	67	1204	2400	1738	2125	0·50	0·69	0·87
643	Mollisoni ...	1929–30	10's B	9·7	62·8	8·6	63	10·1	11·4	20·3	1·20	11·7	66	10·0	187·0	4·6	64	609	1870	1151	1554	0·33	0·53	0·83
648	K. 22	1929–30	,,	10·0	120·8	5·6	67	10·4	16·7	14·6	0·93	8·8	67	10·2	217·4	2·8	68	1208	2217	1737	1817	0·54	0·70	0·82
690	J.N. 1 ...	1929–30	,,	10·1	114·6	7·6	66	10·2	17·3	12·5	1·09	7·2	66	10·1	232·4	2·8	69	1157	2347	1765	2164	0·49	0·66	0·92
	Mean (3) ...	—	,,	9·9	99·4	7·3	65	10·2	15·1	15·8	1·07	9·2	66	10·1	212·3	3·4	67	991	2145	1551	1845	0·45	0·63	0·86
698	Wagad 8 ...	1929–30	12's A	12·3	92·6	6·2	65	12·7	13·4	10·9	0·97	8·6	67	12·1	188·6	2·7	65	1139	2282	1702	1857	0·50	0·67	0·81
648	K. 22	1929–30	12's B	12·0	79·9	7·9	65	12·3	13·0	11·8	0·86	9·7	67	12·6	145·4	4·3	67	959	1832	1599	1547	0·52	0·60	0·84
690	J.N. 1 ...	1929–30	,,	11·6	90·8	7·5	68	12·0	14·1	15·0	1·03	7·2	70	12·1	184·6	2·4	67	1053	2234	1692	1961	0·47	0·62	0·88
	Mean (2) ..	—	,,	11·8	85·3	7·7	66	12·1	13·5	13·4	0·94	8·4	68	12·3	165·0	3·4	67	1006	2033	1645	1754	0·49	0·61	0·86
493	Wagad 4 ...	1928–29	14's A	14·3	94·9	4·8	72	14·6	12·8	9·9	1·08	7·7	72	14·5	162·2	3·3	70	1357	2352	1869	2271	0·58	0·73	0·97
494	Wagad 8 ...	1928–29	,,	14·3	92·4	4·8	72	14·8	12·5	9·6	0·98	7·2	70	14·2	156·4	3·3	66	1321	2221	1850	2040	0·59	0·71	0·92
698	,, ...	1929–30	,,	14·3	75·2	5·8	68	14·7	11·2	13·6	0·93	8·7	67	14·2	157·4	2·3	68	1075	2235	1646	1722	0·48	0·65	0·77
	Mean (3) ...	—	,,	14·3	87·5	5·1	71	14·7	12·2	11·0	1·00	7·9	70	14·3	158·7	3·0	68	1251	2269	1788	2011	0·55	0·70	0·89
648	K. 22	1929–30	14's B	14·0	61·0	8·1	66	14·4	10·5	16·2	0·80	10·1	66	14·0	126·8	3·4	64	854	1775	1512	1361	0·48	0·56	0·77
690	J.N. 1	1929–30	,,	13·5	71·3	9·1	67	13·7	11·9	15·3	0·94	8·1	64	13·8	160·4	2·8	67	962	2213	1630	1724	0·43	0·60	0·78
	Mean (2) ...	—	,,	13·7	66·1	8·6	66	14·0	11·2	15·7	0·87	9·1	65	13·9	143·6	3·1	65	908	1994	1571	1542	0·45	0·58	0·77
493	Wagad 4 ...	1928–29	18's	18·1	65·9	6·1	74	18·5	9·3	10·2	0·99	9·0	72	18·2	108·2	3·3	61	1193	1969	1720	1916	0·61	0·69	0·97
494	Wagad 8 ...	1928–29	,,	18·1	62·0	6·7	66	17·9	9·4	11·3	0·87	7·5	64	18·3	107·8	4·1	70	1122	1973	1683	1647	0·57	0·67	0·83
	Mean (2) ...	—	,,	18·1	63·9	6·4	70	18·2	9·3	10·7	0·93	8·2	68	18·2	108·0	3·7	65	1157	1971	1701	1781	0·59	0·68	0·96

Note—C.S.P. = Count-strength product; C.W.P. = Count-work product.

Appendix: Table VI
Results for 20's Counts—(Ballistic Tests with Lea-ends Free)

Sample No.	Cotton	Season	Lea Tests				Single Thread Tests						Ballistic Tests				Lea C.S.P.	Ballistic C.W.P.	Single Thread C.S.P.	Single Thread C.W.P.	Lea C.S.P. ÷ Ballistic C.W.P.	Lea C.S.P. ÷ Single Thread C.S.P.	Single Thread C.W.P. ÷ Ballistic C.W.P.
			Counts Actual	Strength (lb.)	Irregularity (%)	Relative Humidity (%)	Counts Actual	Strength (oz.)	Irregularity (%)	Extension (inch)	Irregularity (%)	Relative Humidity (%)	Counts Actual	Work of Rupture (inch-lb.)	Irregularity (%)	Relative Humidity (%)							
245	Dharwar 1	H 1926–27	19·0	98·6	5·0	80	19·1	13·3	10·2	0·85	7·5	78	19·1	164·2	5·7	77	1873	3136	2540	2429	0·60	0·74	0·77
"	"	L "	19·2	96·9	4·5	79	19·5	12·8	9·1	0·96	6·3	76	19·6	158·2	4·9	77	1860	3100	2496	2696	0·60	0·74	0·87
373	"	1927–28	20·0	88·7	5·6	69	20·2	12·3	12·1	0·79	8·5	68	20·1	153·1	5·3	68	1774	3077	2485	2212	0·58	0·71	0·72
244	Gadag 1	H 1926–27	19·4	99·4	4·0	78	19·7	13·4	11·6	0·94	7·6	81	19·2	188·4	5·0	85	1928	3617	2640	2791	0·53	0·73	0·77
"	"	L "	19·2	102·8	5·2	82	19·9	13·3	9·1	1·04	6·8	78	19·3	182·8	4·3	75	1974	3528	2647	3096	0·56	0·75	0·88
368	"	1927–28	19·7	94·1	5·2	65	20·5	13·0	9·5	0·87	8·1	67	20·1	171·3	4·2	68	1657	3443	2665	2612	0·48	0·62	0·76
246	1027 A.L.F.	1926–27	19·6	88·2	4·2	66	—	12·3	8·5	0·81	6·7	65	20·1	142·8	5·7	62	1728	2870	—	—	0·60	—	—
363	"	1927–28	20·0	79·0	6·9	63	20·3	10·5	9·8	0·71	7·8	65	20·0	143·1	7·2	70	1580	2862	2132	1706	0·55	0·74	0·60
232	P.A. 4F	1926–27	19·8	75·2	4·6	78	20·3	10·2	10·8	1·07	6·6	77	19·8	174·6	4·3	78	1489	3457	2070	2492	0·43	0·72	0·72
340	"	1927–28	19·4	66·5	6·5	61	19·5	9·2	13·5	0·89	9·9	67	19·8	141·6	4·8	63	1290	2804	1794	1794	0·46	0·72	0·64
233	P.A. 285F	H 1926–27	19·1	92·0	3·8	73	19·4	12·8	9·7	0·90	6·8	79	19·2	181·2	5·1	75	1757	3479	2483	2514	0·50	0·71	0·72
"	"	L "	19·3	92·6	4·7	78	19·7	13·0	8·3	1·00	8·3	79	19·5	181·8	4·9	76	1787	3545	2561	2880	0·50	0·70	0·81
367	"	1927–28	19·8	85·3	4·1	68	20·1	12·4	10·3	0·82	7·1	68	20·1	158·7	6·0	69	1689	3190	2492	2293	0·53	0·68	0·72
234	P.A. 289F	H 1926–27	19·3	107·5	7·4	81	19·9	14·8	9·5	0·92	8·3	80	19·6	196·8	5·3	77	2075	3857	2945	3047	0·54	0·70	0·79
"	"	L "	19·2	109·1	5·6	78	19·8	14·8	8·5	0·94	7·4	78	19·2	197·8	4·9	77	2095	3798	2930	3098	0·55	0·71	0·82
341	"	1927–28	19·6	104·2	5·3	67	19·5	14·2	10·1	0·78	8·5	65	19·7	185·2	4·8	67	2043	3648	2769	2437	0·56	0·74	0·67
231	C.A. 9	1926–27	19·3	102·4	6·0	81	19·6	12·8	14·7	0·87	7·3	76	19·2	182·4	5·3	80	1976	3491	2508	2458	0·57	0·79	0·70
349	" ...	1927–28	19·9	76·6	5·7	70	20·3	10·4	16·1	0·65	10·5	65	20·1	140·9	5·5	66	1524	2832	2111	1541	0·54	0·72	0·54
265	Co. 1	H 1926–27	19·8	103·7	3·9	77	19·9	13·6	8·6	0·95	6·2	78	20·1	178·8	4·4	78	2053	3594	2706	2892	0·57	0·76	0·80
"	"	L "	19·6	102·1	4·1	74	19·5	14·1	7·6	0·96	6·2	76	19·4	190·6	3·9	82	2001	3698	2749	2969	0·54	0·73	0·80
374	"	1927–28	20·1	89·5	5·0	69	20·3	12·1	8·6	0·78	8·2	69	20·3	156·1	5·6	68	1799	3169	2456	2161	0·57	0·73	0·68
273	Nandyal 14	H 1926–27	19·9	88·7	6·5	71	19·9	12·4	10·3	0·81	6·3	71	20·0	181·0	5·1	72	1765	3620	2468	2249	0·49	0·71	0·62
"	"	L "	20·0	87·1	7·7	75	20·3	12·2	10·5	0·76	8·2	72	20·0	178·6	5·1	75	1742	3572	2477	2117	0·49	0·70	0·59
378	"	1927–28	19·6	81·9	9·6	70	20·5	10·9	12·8	0·76	8·0	68	19·9	169·5	4·6	68	1605	3373	2235	1911	0·48	0·72	0·57
269	Hagari 25	H 1926–27	20·0	75·4	6·5	75	20·3	10·6	13·2	0·79	8·9	80	20·3	138·0	6·3	76	1508	2801	2152	1912	0·54	0·70	0·68
"	"	L "	19·8	78·1	6·5	79	19·9	10·6	12·0	0·79	8·5	73	19·9	142·8	5·7	74	1546	2842	2109	1874	0·54	0·73	0·66
377	"	1927–28	19·3	78·8	4·9	69	19·6	10·6	12·7	0·80	8·9	68	19·5	147·7	6·0	68	1521	2880	2078	1870	0·53	0·73	0·65
270	Karunganni C	H 1926–27	20·1	68·6	6·8	75	20·3	9·5	14·6	0·74	7·7	72	20·4	135·0	6·1	70	1379	2754	1928	1604	0·50	0·71	0·58
"	"	L "	20·4	62·6	6·1	67	20·9	9·8	13·2	0·70	6·6	71	20·7	139·4	6·5	70	1277	2886	2048	1613	0·44	0·62	0·56
383	"	1927–28	19·8	70·5	6·6	69	19·9	10·7	14·4	0·70	8·1	69	20·0	146·7	6·1	71	1396	2924	2129	1682	0·48	0·66	0·57
203	Umri Bani	1926–27	20·5	64·2	7·3	43	—	10·0	13·3	0·70	9·7	46	20·7	135·8	6·5	64	1313	2811	—	—	0·47	—	—
333	" "	1927–28	20·1	65·9	6·4	67	21·7	9·4	15·2	0·81	8·4	67	20·2	143·4	6·2	67	1325	2897	2040	1856	0·46	0·65	0·64
	Mean values ...	—	19·7	86·8	5·4	72	20·0	11·9	11·2	0·84	7·8	72	19·8	163·4	5·4	72	1698	3236	2395	2294	0·52	0·71	0·70

Note—C.S.P. = Count-strength product C.W.P. = Count-work product; H = High spinning speed L = Low spinning speed.

Appendix: Table VII
Results for 30's Counts—(Ballistic Tests with Lea-ends Free)

Sample No.	Cotton	Season	Lea Tests: Counts Actual	Lea Tests: Strength (lb)	Lea Tests: Irregularity (%)	Lea Tests: Relative Humidity (%)	Single Thread Tests: Counts Actual	Single Thread Tests: Strength (oz.)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Extension (inch)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Relative Humidity (%)	Ballistic Tests: Counts Actual	Ballistic Tests: Work of Rupture (inch-lb.)	Ballistic Tests: Irregularity (%)	Ballistic Tests: Relative Humidity (%)	Lea C.S.P.	Ballistic C.W.P.	Single Thread C.S.P.	Single Thread C.W.P.	Lea C.S.P. ÷ Ballistic C.W.P.	Lea C.S.P. ÷ Single Thread C.S.P.	Single Thread C.W.P. ÷ Ballistic C.W.P.
245	Dharwar 1	H 1926–27	28·6	56·2	4·5	80	30·4	7·5	13·3	0·69	9·5	77	29·0	97·4	6·9	77	1607	2825	2280	1769	0·57	0·70	0·63
,,	,,	L ,,	29·4	52·2	6·0	78	30·4	7·5	12·8	0·79	10·3	78	29·3	97·0	5·6	79	1535	2842	2280	2026	0·54	0·67	0·71
373	,,	1927–28	30·0	50·7	7·7	67	30·4	7·3	14·8	0·69	8·5	68	30·0	93·8	5·8	67	1521	2814	2219	1686	0·54	0·68	0·60
244	Gadag 1	H 1926–27	28·6	60·5	4·7	79	29·7	8·7	10·5	0·82	7·1	79	28·6	119·4	5·6	83	1730	3415	2584	2383	0·51	0·67	0·70
,,	,,	L ,,	28·9	58·8	4·6	78	30·4	8·2	12·3	0·92	8·3	80	29·0	116·4	5·6	79	1699	3376	2493	2580	0·50	0·68	0·76
368	,,	1927–28	30·1	57·5	5·1	70	30·7	8·0	12·5	0·80	9·5	69	30·9	108·1	6·0	68	1731	3340	2456	2210	0·52	0·70	0·66
246	1027 A.L.F.	1926–27	29·3	52·6	4·9	64	—	7·9	10·9	0·71	8·3	63	29·6	91·2	7·1	65	1535	2695	—	—	0·57	—	—
363	,,	1927–28	29·6	49·4	5·9	70	29·3	7·0	14·2	0·64	10·2	65	30·3	84·9	8·5	67	1462	2572	2051	1477	0·57	0·71	0·57
232	P.A. 4F	1926–27	29·5	44·8	4·9	77	29·6	6·8	14·2	0·94	10·7	79	29·5	104·3	6·3	76	1318	3077	2012	2128	0·43	0·65	0·69
233	P.A. 285F	H 1926–27	29·3	54·5	4·4	75	29·5	8·2	9·3	0·78	8·9	77	29·4	109·4	6·9	71	1597	3216	2419	2122	0·50	0·66	0·66
,,	,,	L ,,	29·1	53·9	4·4	76	29·3	7·9	12·5	0·85	10·1	79	29·0	115·4	6·7	83	1568	3347	2315	2213	0·50	0·68	0·66
367	,,	1927–28	30.0	51·8	5·5	68	30·4	7·4	11·5	0·69	9·5	69	30·6	97·9	7·8	67	1554	2996	2250	1746	0·52	0·69	0·58
234	P.A. 289F	H 1926–27	29·2	60·3	6·4	79	30·0	9·2	11·0	0·82	8·1	79	29·1	128·6	7·2	76	1761	3742	2760	2546	0·47	0·64	0·68
,,	,,	L ,,	28·7	61·5	6·7	82	29·8	9·2	11·7	0·83	9·9	77	28·6	122·4	6·0	79	1765	3501	2742	2561	0·50	0·64	0·73
341	,,	1927–28	30·1	60·4	5·0	66	30·2	9·0	11·6	0·65	10·7	65	30·1	112·2	6·0	66	1818	3377	2718	1984	0·54	0·67	0·59
231	C.A. 9	1926–27	29·3	61·1	3·8	79	29·3	8·7	12·0	0·80	8·0	74	29·0	111·6	7·1	79	1786	3229	2549	2294	0·55	0·70	0·71
349	,,	1927–28	30·5	47·0	7·1	64	29·9	7·5	12·8	0·62	8·9	64	30·3	89·3	7·2	60	1434	2706	2243	1570	0·53	0·64	0·58
265	Co. 1	H 1926–27	29·0	62·3	5·6	78	29·7	8·8	11·5	0·87	8·3	79	28·8	121·0	6·4	82	1807	3485	2614	2558	0·52	0·69	0·73
,,	,,	L ,,	29·6	59·6	4·4	77	30·3	8·8	11·1	0·86	8·7	80	29·3	120·2	5·9	81	1764	3522	2666	2579	0·50	0·66	0·73
374	,,	1927–28	30·4	52·8	5·0	68	30·9	7·3	11·5	0·67	9·5	68	30·8	95·1	6·0	66	1605	2929	2256	1700	0·55	0·71	0·58
273	Nandyal 14	H 1926–27	30·1	54·0	7·8	76	30·6	7·7	12·8	0·72	7·9	72	30·3	98·8	6·5	67	1625	2994	2356	1908	0·54	0·69	0·64
,,	,,	L ,,	30·0	56·6	7·7	79	30·4	8·3	12·1	0·69	9·2	75	30·4	103·2	7·5	80	1698	3137	2523	1958	0·54	0·67	0·62
378	,,	1927–28	29·5	50·2	9·8	68	30·3	7·4	17·2	0·67	13·5	69	30·4	106·4	6·9	72	1481	3235	2242	1690	0·46	0·66	0·52
269	Hagari 25	H 1926–27	29·4	47·7	4·9	77	29·0	7·3	13·7	0·70	10·7	78	29·6	88·8	6·6	75	1402	2628	2117	1666	0·53	0·66	0·63
,,	,,	L ,,	29·9	46·8	6·0	74	30·7	6·6	13·7	0·66	11·9	72	30·0	82·6	7·5	71	1399	2478	2026	1504	0·56	0·69	0·61
377	,,	1927–28	29·6	45·2	5·1	68	29·3	6·6	13·8	0·67	9·6	70	30·1	84·5	7·5	71	1338	2543	1934	1458	0·53	0·69	0·57
270	Karunganni C	H 1926–27	30·4	40·5	9·3	71	30·5	6·5	13·8	0·68	10·0	72	30·0	88·6	6·1	71	1231	2658	1982	1516	0·46	0·62	0·57
,,	,,	L ,,	30·7	38·5	10·0	71	31·3	6·6	13·0	0·63	8·9	70	31·0	84·0	6·9	69	1182	2604	2066	1464	0·45	0·57	0·56
383	,,	1927–28	29·9	42·2	12·1	67	31·2	6·5	12·6	0·62	10·9	67	29·7	88·4	5·8	74	1262	2625	2028	1415	0·48	0·62	0·54
333	Umri Bani	1927–28	29·9	39·9	10·8	69	31·2	5·8	15·6	0·68	12·4	69	29·9	89·8	7·1	63	.193	2685	1810	1385	0·44	0·66	0·52
	Mean values	—	29·6	52·3	6·3	73	30·2	7·7	12·7	0·74	9·6	73	29·8	101·7	6·6	73	,547	3020	2310	1934	0·51	0·67	0·68

Note—C S P = Count-strength product C W P = Count-work product H = High spinning speed; L = Low spinning speed

Appendix: Table VIII

Results for 40's Counts—(Ballistic Tests with Lea-ends Free)

Sample No.	Cotton	Season	Lea Tests: Counts Actual	Lea Tests: Strength (lb.)	Lea Tests: Irregularity (%)	Lea Tests: Relative Humidity (%)	Single Thread Tests: Counts Actual	Single Thread Tests: Strength (oz.)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Extension (inch)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Relative Humidity (%)	Ballistic Tests: Counts Actual	Ballistic Tests: Work of Rupture (inch-lb.)	Ballistic Tests: Irregularity (%)	Ballistic Tests: Relative Humidity (%)	Lea C.S.P.	Ballistic C.W.P.	Single Thread C.S.P.	Single Thread C.W.P.	Lea C.S.P. ÷ Ballistic C.W.P.	Lea C.S.P. ÷ Single Thread C.S.P.	Single Thread C.W.P. ÷ Ballistic C.W.P.
245	Dharwar 1	H 1926–27	38·5	35·1	5·0	76	39·2	5·6	15·6	0·63	13·4	77	38·5	67·4	6·8	79	1351	2595	2195	1555	0·52	0·62	0·60
„	„	L „	38·3	34·5	4·7	78	39·0	5·4	15·7	0·74	11·0	76	38·3	69·4	7·2	79	1321	2658	2106	1753	0·50	0·63	0·66
244	Gadag 1	H 1926–27	38·7	38·9	6·0	77	39·4	6·2	13·3	0·75	10·1	80	37·7	85·0	6·4	80	1505	3129	2443	2061	0·48	0·62	0·66
„	„	L „	38·7	37·0	6·2	81	40·2	5·7	13·2	0·84	10·6	79	37·9	79·0	6·3	80	1432	2994	2291	2165	0·48	0·62	0·72
368	„ .. .	1927–28	39·4	38·8	5·3	67	40·5	6·1	11·7	0·71	10·2	69	40·4	82·8	7·7	70	1529	3345	2470	1976	0·46	0·62	0·59
233	P.A. 285F . ..	H 1926–27	38·9	36·9	4·7	74	38·7	5·9	13·0	0·67	10·7	79	38·9	78·4	5·8	76	1435	3050	2283	1721	0·47	0·63	0·56
„	„	L „	38·8	35·8	5·8	77	40·3	5·5	13·0	0·76	13·2	79	38·4	82·4	7·0	79	1389	3164	2216	1894	0·44	0·63	0·60
367	„	1927–28	39·9	35·2	6·6	67	40·5	5·5	13·7	0·62	13·0	67	39·8	72·8	8·5	68	1404	2897	2227	1553	0·48	0·63	0·54
234	P.A. 289F	H 1926–27	38·6	41·3	5·7	80	39·0	6·8	11·6	0·76	10·6	78	37·9	93·4	7·3	76	1594	3540	2652	2267	0·45	0·60	0·64
„	„	L „	38·3	42·6	6·1	82	39·8	6·4	14·7	0·83	11·1	82	38·7	82·8	7·1	80	1632	3204	2547	2378	0·51	0·64	0·74
341	„	1927–28	40·5	40·1	4·9	65	40·4	6·4	12·9	0·57	14·9	66	40·5	77·4	6·2	66	1624	3135	2586	1655	0·52	0·63	0·53
231	C.A. 9	1926–27	39·6	39·3	6·4	78	40·6	5·8	14·4	0·71	10·0	72	38·8	75·1	7·0	79	1556	2913	2355	1884	0·53	0·66	0·65
349	„	1927–28	40·0	33·6	7·1	57	39·9	5·5	14·6	0·53	13·6	65	40·1	62·3	7·9	61	1344	2498	2195	1308	0·54	0·61	0·52
265	Co. 1	H 1926–27	40·2	37·7	5·3	81	40·7	5·9	13·9	0·78	10·1	79	40·7	79·0	7·7	78	1516	3215	2401	2107	0·47	0·63	0·65
„	„	L „	39·4	38·8	5·0	76	39·7	6·1	13·9	0·80	10·5	79	39·1	86·2	8·1	85	1529	3370	2422	2180	0·45	0·63	0·65
374	„	1927–28	40·7	35·1	4·7	68	40·9	5·3	14·2	0·61	11·1	67	40·6	71·5	7·4	70	1429	2903	2168	1487	0·49	0·66	0·51
273	Nandyal 14	H 1926–27	39·6	38·8	7·5	77	40·5	5·6	13·8	0·65	10·1	73	39·7	72·0	7·7	71	1536	2858	2268	1658	0·54	0·68	0·58
„	„	L „	40·1	39·1	7·6	80	40·1	6·0	11·7	0·60	12·4	71	40·0	76·8	7·3	81	1568	3072	2406	1624	0·51	0·65	0·53
269	Hagari 25	H 1926–27	39·6	30·4	6·2	77	40·2	4·8	14·7	0·61	12·9	75	39·6	61·8	7·7	77	1204	2447	1930	1324	0·49	0·62	0·54
„	„	L „	40·0	30·1	6·1	74	40·3	4·7	15·8	0·60	12·5	72	40·2	59·6	8·8	68	1204	2396	1894	1278	0·50	0·64	0·53
	Mean values	—	39·4	37·0	5·8	75	40·0	5·8	13·8	0·69	11·6	74	39·3	75·7	7·3	75	1455	2969	2303	1791	0·49	0·63	0·60

Note—C.S.P.=Count-strength product; C.W.P.=Count-work product; H=High spinning speed; L=Low spinning speed.

Appendix: Table IX
Results for Low and Very Low Counts—(Ballistic Tests with Lea-ends Free)

Sample No.	Cotton	Season	Counts Nominal	Lea Tests: Counts Actual	Lea Tests: Strength (lb.)	Lea Tests: Irregularity (%)	Lea Tests: Relative Humidity (%)	Single Thread Tests: Counts Actual	Single Thread Tests: Strength (oz.)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Extension (inch)	Single Thread Tests: Irregularity (%)	Single Thread Tests: Relative Humidity (%)	Ballistic Tests: Counts Actual	Ballistic Tests: Work of Rupture (inch-lb.)	Ballistic Tests: Irregularity (%)	Ballistic Tests: Relative Humidity (%)	Lea C.S.P.	Ballistic C.W.P.	Single Thread C.S.P.	Single Thread C.W.P.	Lea C.S.P. ÷ Ballistic C.W.P.	Lea C.S.P. ÷ Single Thread C.S.P.	Single Thread C.W.P. ÷ Ballistic C.W.P.
227	A. 19	1926–27	6's	5·8	116·5	3·9	66	—	18·7	15·2	1·17	12·1	63	6·0	385·8	3·8	63	676	2315	—	—	0·29	—	—
230	Mollisoni ...	1926–27	,,	5·9	140·7	3·8	82	5·8	18·7	16·2	1·45	9·7	77	5·8	495·0	4·0	81	830	2871	1085	1770	0·29	0·76	0·62
	Mean	—	,,	5·8	128 6	3·8	74	5·8	18 7	15·7	1·31	10·9	69	5·9	440·4	3·9	72	753	2593	1085	1770	0·29	0·76	0·62
227	A. 19	1926–27	8's	7·8	75·2	7·5	64	—	15·7	13·6	1·07	9·4	64	7·6	280·8	6·2	64	587	2134	—	—	0·27	—	—
352	,, ...	1927–28	,,	7·9	87·9	8·3	38	8·1	15 0	16·8	0·88	9·9	44	7·8	431·6	3·9	40	694	3367	1215	1203	0·21	0·57	0·36
230	Mollisoni ...	1926–27	,,	7·7	111·3	6·6	80	7·6	15·5	18·5	1·51	9·4	80	7·8	351·6	3·5	80	857	2743	1178	2001	0·31	0·73	0·73
324	,, ...	1927–28	,,	7·9	101 8	8·4	67	8·2	13·5	16·4	1·07	8·6	67	8·2	258·8	4·9	67	804	2122	1107	1332	0·38	0·73	0·63
	Mean	—	,,	7·8	94·0	7·7	62	8 0	14·9	16·3	1·13	9·3	64	7·8	330·7	4·6	63	735	2591	1166	1512	0·29	0·68	0·57
227	A. 19	1926–27	10's	10·1	42·6	11·1	65	—	10·5	21·1	0·88	13·0	63	10·1	182·4	6·3	65	430	1842	—	—	0·23	—	—
352	,, ...	1927–28	,,	9 9	51·9	10·6	56	10·1	11·2	17·1	0·78	13·5	51	9·8	188·8	5·3	68	514	1850	1131	992	0·28	0·45	0·54
228	K. 22	1926–27	,,	9·7	107 2	4·3	70	—	16·5	14·4	1·04	7·6	63	9·9	280·4	4·6	63	1040	2776	—	—	0·37	—	—
351	,, ...	1927–28	,,	10·0	99·9	6·9	65	10·4	14·5	12·6	0·90	8·7	57	10·2	246 0	5·3	68	999	2509	1508	1526	0·40	0·66	0·61
229	J.N. 1 ...	1926–27	,,	9·9	118·5	6·7	81	9 2	17·9	14·1	1·11	8·6	77	9 8	314·0	3·6	78	1173	3077	1647	2056	0·38	0·71	0·67
350	,, ...	1927–28	,,	10·5	108·5	5·8	41	10·5	17·8	11·4	0·82	8·7	47	10·4	240·6	6·0	54	1140	2502	1869	1724	0·45	0·61	0·69
271	Wagad 8 ...	1926–27	,,	9·9	137·7	5·4	71	10·3	17·3	13·8	1·01	6·0	69	10·1	283·6	4·4	71	1363	2864	1782	2024	0·48	0·76	0·71
372	,, ...	1927–28	,,	10·5	134·1	3·6	68	11·0	17·0	9·4	1·16	6·4	68	10·6	310·6	4·0	67	1408	3293	1870	2440	0·43	0·75	0·74
272	Wagad 4 ...	1926–27	,,	10·0	155·9	3·6	76	10·2	20·1	10·4	1·11	7·5	70	10·0	323·8	4·0	77	1559	3238	2050	2560	0·48	0·76	0·79
371	,, ...	1927–28	,,	10·8	142·1	3·8	68	11·0	18·5	9·3	1·11	6·5	67	10·8	292·0	3·9	68	1535	3154	2035	2541	0·49	0·75	0·81
324	Mollisoni ...	1927–28	,,	9·9	68·9	6·9	67	10·1	11·3	14·6	1·01	8·6	68	10 0	203·8	4·7	68	682	2038	1141	1296	0·33	0 60	0·64
	Mean	—	,,	10·1	106·2	6·2	66	10·3	15·7	13·5	0·99	8·6	64	10·2	260·5	4·7	68	1077	2649	1670	1907	0·39	0·67	0·69
228	K. 22	1926–27	12's	11·9	93·7	5·6	68	—	13·9	14·0	1·03	7·5	64	12·0	227·4	5·4	66	1115	2729	—	—	0·41	—	—
351	,, ...	1927–28	,,	11·7	94·8	7·0	63	12·0	14·4	14·7	0 97	8·1	67	12 0	197·4	4·9	66	1109	2369	1728	1886	0·47	0·64	0·80
229	J.N. 1 ...	1926–27	,,	11·7	112·6	6·9	83	10·9	17·0	11·6	1·11	7·5	77	11·7	260·6	4·6	80	1317	3049	1853	2314	0·43	0·71	0·76
350	,, ...	1927–28	,,	12·6	96·5	5·0	39	12·6	14·9	13·4	0·85	9·2	59	12·3	219·6	5·7	68	1216	2701	1877	1795	0·45	0·65	0·66
	Mean	—	,,	12·0	99·4	6·1	63	11·8	15·0	13·4	0·99	8·1	67	12·0	226·2	5·1	70	1189	2712	1819	1998	0·44	0·67	0·74
228	K. 22	1926–27	14's	13·9	73·7	7·1	70	—	11·4	9·9	0·99	7·1	67	14·2	173·6	4·9	66	1024	2465	—	—	0·42	—	—
351	,, ...	1927–28	,,	14·0	68·9	7·9	65	14·5	10 7	15·2	0 86	8·0	68	14·3	153·4	4·7	63	965	2194	1552	1501	0·44	0·62	0·68
229	J.N. 1 ..	1926–27	,,	13·7	91·8	8·6	83	13·4	12·8	15·8	1·02	8·8	79	13·7	204·8	4·8	77	1259	2805	1715	1968	0·45	0·73	0·70
350	,, ...	1927–28	,,	14·2	81·1	5·9	41	14·3	13·5	12·3	0·86	8·4	68	14·1	174·0	4·7	74	1152	2453	1931	1867	0·47	0·60	0·76
271	Wagad 8 ...	1926–27	,,	14·0	88·4	6·0	73	14·4	11·8	12·9	0·95	7·3	72	14·4	176·8	6·2	70	1238	2546	1699	1817	0·49	0·73	0·71
372	,, ...	1927–28	,,	14·6	88·8	4·6	69	14·8	11·8	10·0	1·01	9·0	70	14·6	206·0	4·5	68	1296	3008	1747	1985	0·43	0·74	0·66
272	Wagad 4 ...	1926–27	,,	14·4	94·5	5·6	73	14·6	13·3	11·0	0·96	6·6	68	14·6	189·2	5·4	73	1361	2764	1942	2097	0·49	0·70	0·76
371	,, ...	1927–28	,,	14·5	99·6	4·2	68	14·8	13·8	8·1	1·01	5·9	68	14·5	205·2	4·6	67	1449	2976	2043	1819	0·49	0·71	0·61
	Mean	—	—	14·2	85·8	6·2	68	14·4	12·4	11·9	0·96	7·6	70	14·3	185·4	5·0	70	1218	2651	1804	1865	0·46	0·69	0·70

Note—C.S.P. = Count-strength product. C.W.P. = Count-work product

13—CRIMP IN WOOL AS A PERIODIC FUNCTION OF TIME

II—A STUDY OF 31 SAMPLES CUT FROM THE SAME MERINO SHEEP AT INTERVALS OF ONE MONTH DURING ITS WHOLE LIFE

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PART I—CRIMP

In continuation of work recently published,[1] we have been able to study, through the kindness of Prof. Duerden, of University College, Grahamston, South Africa, a unique set of samples of Merino wool, all taken from the same sheep at monthly intervals during its entire life of 31 months. The first sample was taken at birth. In view of the interesting results obtained from our previous study, it seemed probable that a similar examination of these samples could not fail to provide further valuable data.

The measurements were carried out in exactly the same way as those described previously,[1] and the results are presented in Table I below. The figures seem to supply definite support to the hypothesis that crimp formation is a periodic function of time and is not dependent on rate of fibre growth. Although the crucial test of such an hypothesis must of necessity be measurements made while the wool is still on the sheep, the great difficulties involved in obtaining a set of such measurements, which would be entirely trustworthy, renders any data which throws further light on the problem valuable, even if not conclusive.

Table I

Analysis of Locks of Merino Wool, from the same Sheep taken at Monthly Intervals, for Fibre Length and Number of Crimps per Fibre

Length* Group (cms.)	*f*	Mean Number of Crimps: Per fibre	Mean Number of Crimps: Per cm †	M.‡	S D	Coefficient of Variation
(1) AGE 1 MONTH§ (32 DAYS): MEAN FIBRE LENGTH 2 CMS						
1·1 1·5	9	4	3·08	5·6	±1·35	24·0%
1·6–2·0	50	5	2·78			
2·1–2·5	40	6·5	2·83			
(2) AGE 3 MONTHS (93 DAYS): MEAN FIBRE LENGTH 3·4 CMS.						
2·1–2·5	21	9	3·91	12·2	±2·94	24·2%
2·6–3·0	12	11	3·93			
3·1–3·5	15	12	3·64			
3·6–4·0	19	13	3·42			
4·1–4·5	25	14	3·26			
4·6–5·0	5	16	3·33			
(3) AGE 4 MONTHS (124 DAYS): MEAN FIBRE LENGTH 4·0 CMS.						
2·1–2·5	6	13	5·65	15·5	±8·22	18·4%
2·6–3·0	10	14	5·00			
3·1–3·5	25	15	4·55			
3·6–4·0	18	16	4·21			
4·1–4·5	12	18	4·19			
4·6–5·0	11	19	3·96			
5·1–5·5	11	20	3·77			

Table I—*continued*

Length* Group (cms.)	*f*	Mean Number of Crimps Per fibre	Mean Number of Crimps Per cm †	M.‡	S.D.	Coefficient of Variation
(4) Age 5 Months (154 days). Mean Fibre Length 5·7 cms						
3·1–4·0	6	17	4·79	24·2	±3·55	14·7%
4·1–5·0	20	20	4·40			
5·1–6·0	34	25	4·50			
6·1–7·0	45	26	3·97			
7·1–8·0	17	26	3·44			
(5) Age 7 Months (220 days): Mean Fibre Length 7·0 cms						
4·6–5·5	11	26	5·15	30·3	±3·21	10·6%
5·6–6·5	27	28	4·63			
6·6–7·5	30	31	4·40			
7·6–8·5	23	33	4·10			
8·6–9·5	9	33	3·65			
(6) Age 8 Months (248 days): Mean Fibre Length 8·3 cms						
6·1– 7·0	9	32	4·89	34·2	±2·71	7·9%
7·1– 8·0	18	33	4·37			
8·1– 9·0	50	35	4·09			
9·1–10·0	20	35	3·66			
(7) Age 9 Months (276 days): Mean Fibre Length 8·5 cms.						
6·1– 7·0	10	31	4·73	34·2	±3·36	9·85%
7·1– 8·0	23	33	4·37			
8·1– 9·0	39	34	3·98			
9·1–10·0	21	35	3·66			
10·1–11·0	6	36	3·41			
(8) Age 10 Months (304 days). Mean Fibre Length 9·3 cms.						
7·1– 8·0	7	38	5·03	41·0	±3·24	7·90%
8·1– 9·0	31	40	4·68			
9·1–10·0	39	42	4·40			
10·1–11·0	22	43	4·08			
(9) Age 11 Months (332 days): Mean Fibre Length 11·0 cms.						
8·6– 9·5	7	44	4·86	46·7	±3·18	6·80%
9·6–10·5	27	46	4·58			
10·6–11·5	36	47	4·25			
11·6–12·5	27	48	3·98			
(10) Age 12 Months (369 days): Mean Fibre Length 12·3 cms						
10·1–11·0	7	51	4·83	52·0	±4·33	8·34%
11·1–12·0	30	51	4·42			
12·1–13·0	29	52	4·14			
13·1–14·0	23	54	3·98			
14·1–15·0	7	54	3·71			
(11) Age 13 Months (397 days): Mean Fibre Length 12·3 cms.						
9·6–10·5	7	45	4·48	52·7	±5·34	10·13%
10·6–11·5	17	48	4·34			
11·6–12·5	33	53	4·40			
12·6–13·5	29	55	4·21			
13·6–14·5	9	58	4·13			
(12) Age 14 Months (430 days): Mean Fibre Length 14·1 cms.						
11·1–12·0	8	52·5	4·55	57·3	±6·62	11·55%
12·1–13·0	11	54	4·30			
13·1–14·0	26	56	4·13			
14·1–15·0	25	57	3·92			
15·1–16·0	20	62	3·99			
16·1–17·0	7	60	3·74			

Table I—*continued*

Length* Group (cms.)	f	Mean Number of Crimps Per fibre	Mean Number of Crimps Per cm †	M ‡	S D	Coefficient of Variation
(13) Age 15 Months (458 days) Mean Fibre Length 15·1 cms						
12·1–13·0	8	63	5·02	66·8	6·73	10·1%
13·1–14·0	17	64·5	4·76			
14·1–15·0	22	64·5	4·43			
15·1–16·0	28	67·5	4·34			
16·1–17·0	14	69	4·17			
17·1–18·0	8	72	4·10			
(14) Age 16 Months (485 days) Mean Fibre Length 15·07 cms						
12·1–13·0	7	58	4·62	63·7	±4·37	6·85%
13·1–14·0	16	62	4·58			
14·1–15·0	26	64	4·40			
15·1–16·0	28	64	4·12			
16·1–17·0	16	66	3·99			
17·1–18·0	5	65	3·70			
(15) Age 17 Months (513 days) Mean Fibre Length 16·75 cms						
13·6–14·5	5	73	5·20	71·4	±4·79	6·70%
14·6–15·5	14	69	4·58			
15·6–16·5	22	73	4·55			
16·6–17·5	24	71	4·16			
17·6–18·5	19	74	4·10			
18·6–19·5	7	74	3·88			
19·6–20·5	5	76	3·79			
(16) Age 18 Months (541 days) Mean Fibre Length 16·5 cms						
14·1–15·0	9	67	4·60	72·6	±5·67	7·8%
15·1–16·0	30	71	4·57			
16·1–17·0	24	75	4·53			
17·1–18·0	22	74·5	4·25			
18·1–19·0	9	74	3·99			
(17) Age 19 Months (570 days) Mean Fibre Length 17·6 cms						
14·6–15·5	8	69	4·58	70·2	±5·20	7·41%
15·6–16·5	21	71	4·42			
16·6–17·5	20	71	4·16			
17·6–18·5	15	70	3·88			
18·6–19·5	22	71	3·73			
19·6–20·5	10	69	3·44			
(18) Age 20 Months (598 days). Mean Fibre Length 16·2 cms						
13·6–14·5	6	71	5·05	73·1	±6·05	8·28%
14·6–15·5	24	71·5	4·75			
15·6–16·5	28	72	4·49			
16·6–17·5	24	75	4·40			
17·6–18·5	9	74	4·10			
18·6–19·5	5	78	4·10			
(19) Age 21 Months (625 days) Mean Fibre Length 19·6 cms						
16·1–17·0	9	78	4·71	85·8	±8·09	9·43%
17·1–18·0	8	82	4·67			
18·1–19·0	17	85	4·58			
19·1–20·0	25	87	4·45			
20·1–21·0	19	86	4·18			
21·1–22·0	8	91	4·22			
22·1–23·0	7	95	4·41			

Table I—*continued*

Length* Group (cms.)		Mean Number of Crimps Per fibre	Mean Number of Crimps Per cm †	M ‡	S D	Coefficient of Variation
(20) Age 22 Months (653 days) Mean Fibre Length 20·6 cms						
17·1–18·0	6	79	4·50	83·2	± 6·45	7·75%
18·1–19·0	19	82	4·42			
19·1–20·0	13	84	4·30			
20·1–21·0	17	83	4·04			
21·1–22·0	19	84	3·90			
22·1–23·0	16	85	3·77			
23·1–24·0	6	85	3·61			
(21) Age 23 Months (681 days) Mean Fibre Length 19·4 cms.						
16·1–17·0	6	75	4·53	83·7	± 6·56	7·84%
17·1–18·0	9	80	4·56			
18·1–19·0	25	82	4·42			
19·1–20·0	22	82	4·19			
20·1–21·0	20	86	4·18			
21·1–22·0	13	88	4·08			
(22) Age 24 Months (709 days) Mean Fibre Length 23·2 cms						
20·1–21·0	5	89	4·33	92·9	± 6·58	7·09%
21·1–22·0	24	90·5	4·20			
22·1–23·0	19	94	4·17			
23·1–24·0	14	93	3·95			
24·1–25·0	15	95	3·87			
25·1–26·0	11	95	3·72			
(23) Age 25 Months (737 days) Mean Fibre Length 23·3 cms						
19·6–20·5	5	88	4·39	96·1	± 8·14	8·46%
20·6–21·5	12	94	4·47			
21·6–22·5	12	94	4·26			
22·6–23·5	22	95	4·12			
23·6–24·5	17	101	4·24			
24·6–25·5	15	98	3·91			
25·6–26·5	6	102	3·92			
26·6–27·5	7	102	3·77			
(24) Age 26 Months (765 days) Mean Fibre Length 23·8 cms						
20·6–21·5	11	101	4·80	106·4	± 8·00	7·51%
21·6–22·5	17	105	4·76			
22·6–23·5	17	106	4·60			
23·6–24·5	16	105	4·37			
24·6–25·5	18	109	4·35			
25·6–26·5	12	113	4·34			
26·6–27·5	6	108	3·99			
(25) Age 27 Months (793 days) Mean Fibre Length 26·3 cms.						
22·6–23·5	14	108	4·69	117·1	± 10·54	9·01%
23·6–24·5	10	110	4·57			
24·6–25·5	9	114	4·55			
25·6–26·5	16	119	4·57			
26·6–27·5	17	122	4·51			
27·6–28·5	14	120	4·28			
28·6–29·5	7	121	4·17			
29·6–30·5	6	125	4·16			

Table I—*continued*

Length* Group (cms)	f	Mean Number of Crimps Per fibre	Mean Number of Crimps Per cm.†	M ‡	S.D.	Coefficient of Variation
(26) Age 28 Months (821 days)· Mean Fibre Length 25·9 cms.						
22·6–23·5	8	108	4·69	113·1	±7·49	6·62%
23·6–24·5	9	108	4·49			
24·6–25·5	20	112	4·47			
25·6–26·5	25	113	4·34			
26·6–27·5	16	114	4·21			
27·6–28·5	9	118	4·21			
28·6–29·5	8	119	4·10			
(27) Age 29 Months (849 days) Mean Fibre Length 27·2 cms						
24·1–25·0	8	111	4·52	117·4	±9·94	8·45%
25·1–26·0	15	116	4·54			
26·1–27·0	19	116	4·37			
27·1–28·0	26	118	4·28			
28·1–29·0	20	121	4·24			
(28) Age 30 Months (877 days): Mean Fibre Length 28·6 cms						
24·6–25·5	8	123	4·91	126·5	±7·69	6·07%
25·6–26·5	8	119·5	4·59			
26·6–27·5	12	124	4·58			
27·6–28·5	19	126	4·49			
28·6–29·5	22	129	4·44			
29·6–30·5	15	127	4·23			
30·6–31·5	6	127·5	4·11			
(29) Age 31 Months (907 days): Mean Fibre Length 28·7 cms.						
25·1–26·0	6	123	4·81	129·5	±9·42	7·28%
26·1–27·0	14	131	4·93			
27·1–28·0	17	132	4·79			
28·1–29·0	19	127	4·45			
29·1–30·0	14	133	4·50			
30·1–31·0	12	133	4·35			
31·1–32·0	10	125	3·96			

*Length groups containing less than five fibres omitted
†Per cm of straightened fibre
‡Mean number of crimps per fibre taking into account every fibre measured.
§Months are reckoned as approximately 28 days

Comparison of the figures in Table I with those presented in Table I of the previous paper[1] shows that the coefficients of variation in total number of crimps per fibre (column 7), except in the case of the first four samples, are no greater than those found for the various Merino wools studied previously. In other words, the general rule that the mean total number of crimps per fibre is approximately the same for each length group, holds to about the same extent as it did with the previous Merino samples.

Nevertheless from an examination of Fig. 1, where data for samples taken at two month intervals are plotted, it is obvious that most of the curves show a tendency to slope slightly upwards rather than remain parallel to the x axis. This tendency is greater the younger the sample and the shorter the fibres. However, the figures of column 4 of Table I show clearly that the number of crimps per cm. of straightened fibre systematically decreases with increase in fibre length. Thus, although the number of crimps per fibre does show a slight but regular increase with increasing length of fibre,

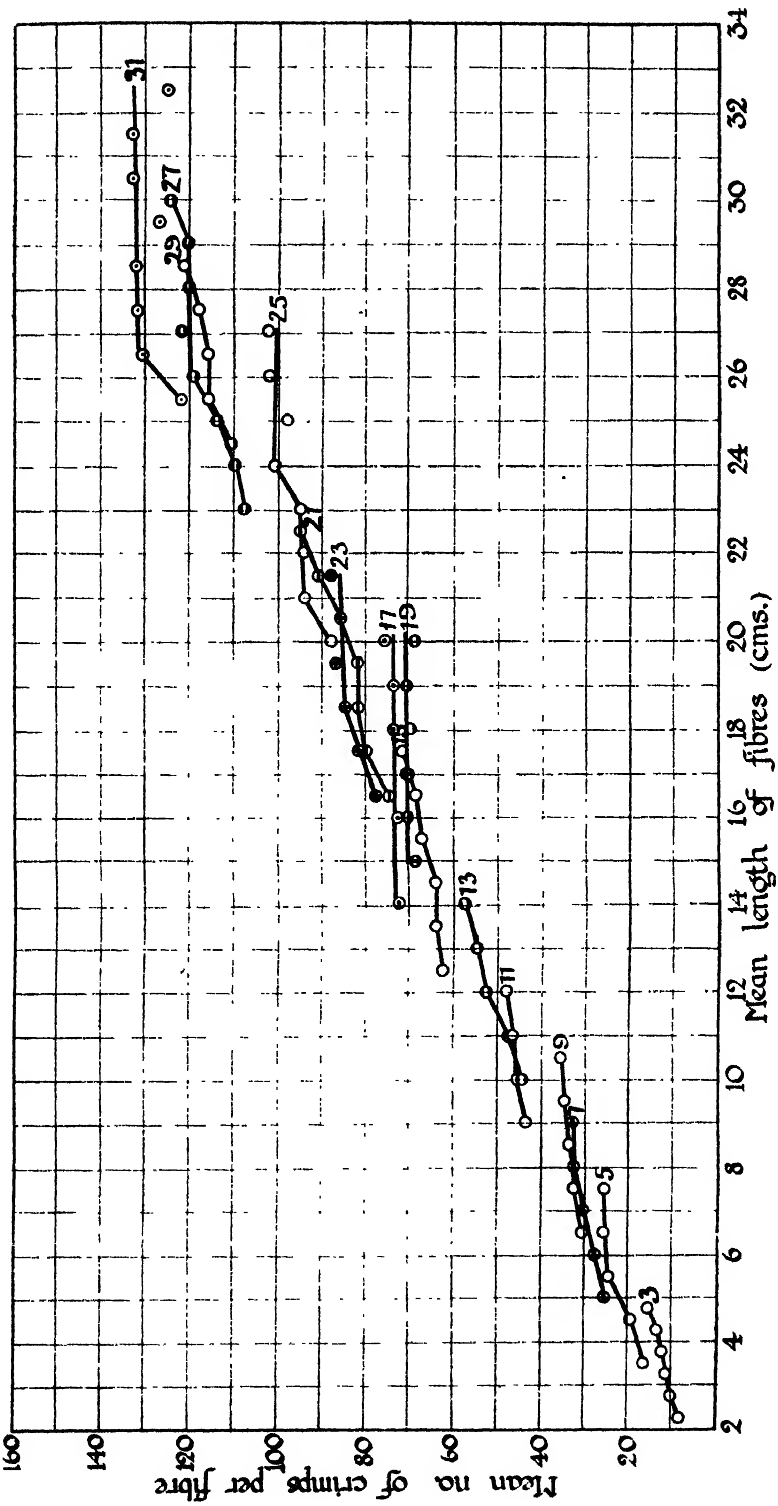
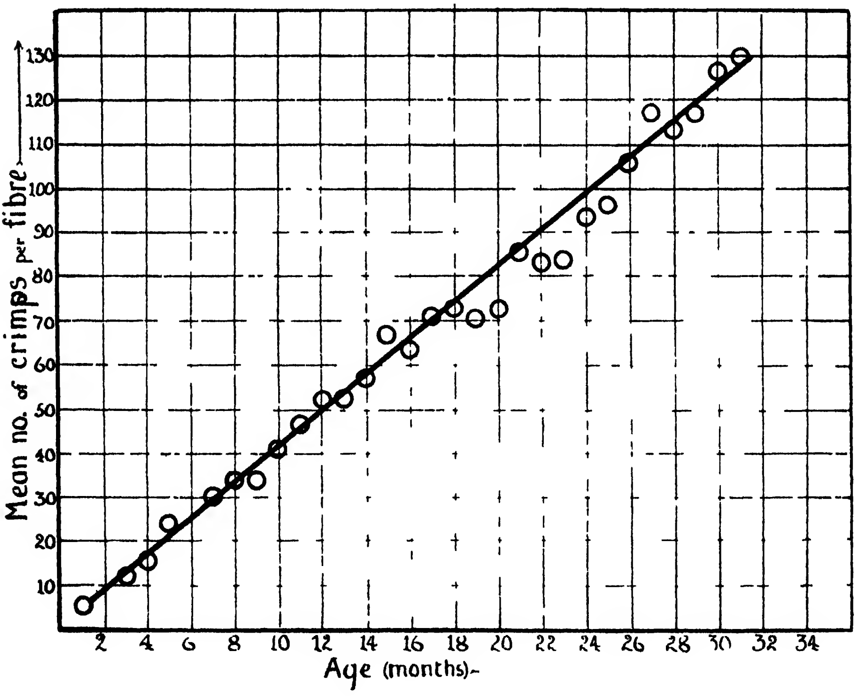


FIG. 1

Samples of Wool from Merino Wether cut every two months.
(Numbers indicate age in months.)

this increase is not sufficient to suggest that the number of crimps produced per fibre is dependent upon the rate of fibre growth (see later).

It will be noticed from the table that many fibre length groups are common to several samples (of different ages), but almost without exception it is found that the older the sheep the greater the mean number of crimps per fibre for fibres of the same length. Thus, consider for example fibres 22·8 cms. long ($\pm$0·2 cms.); at ages 23, 25, 26, 27, and 28 months, the mean number of crimps per fibre for that length of fibre were 86, 92, 96, 103, and 111 respectively. This finding gives strong support to our supposition that crimp formation is in no way dependent upon the length of fibre produced. Fibres 22·8 cms. long, 23 months old, have 86 crimps, whereas



fibres 22·8 cms. long, but 28 months old, have 111 crimps. The older fibres are of course the slower growing ones, since they took 28 months to produce the same length of fibre produced in 23 months by the younger fibres, and, as would be expected, the slower growing fibres have produced more crimps than the faster growing ones for the same length of fibre.

In order to arrive at some very approximate idea of the rate of crimp formation, in Fig. 2 the mean number of crimps per fibre for each sample is plotted against the age of the sample. The figure indicates a fairly uniform increase in the number of crimps with time, and from the slope of the best straight line through the points it is possible to estimate the rate of production of crimps, namely, approximately four crimps per month.

With regard to the explanation of the tendency of the lines in Fig. 1 to slope slightly upwards instead of remaining quite parallel to the x axis, it will be remembered that a similar tendency was noticed with the short fibres of many of the Merino samples described in the previous publication, and it was suggested that these fibres may have started to grow later than the majority of fibres in the lock, or conversely, ceased to grow before the lock was sheared. The evidence from the present data supports this supposition, for it is safe to assume that all these fibres did not start to grow at the same time. Such an assumption explains at once the marked slope of the curves in the case of the samples taken from the very young sheep, and the almost total disappearance of it with the older samples. Thus, at three months the number of crimps for the length groups of mean lengths from 2·25 to 4·75 cms. respectively are 9, 11, 12, 13, 14, and 16, giving a distinctly sloping line. Now, supposing this lack of constancy in the number of crimps can be accounted for on the grounds that the longer fibres were those that started to grow first and the shorter ones started later, this explains the slight tendency for mean number of crimps per fibre to increase with fibre length, for the longer fibres are also the older. Further, as the sheep was never shorn this disturbing influence should continue to affect the data for all the samples studied, although its influence becomes much diminished in the older samples owing to the greater influence of differences in rates of fibre growth. Thus, at age 31 months, assuming four crimps to be produced per month, and the rate of increase in length to be the same for all fibres, we should get 121, 123, 125, 126, and 128 crimps respectively. Actually we get 123, 131, 132, 127, 133, 133, and 125 for length groups of 1 cm. intervals from 25·5 to 31·5 cms. respectively. The line joining these points is much more nearly parallel to the x axis than it was in the case of the sample three months old. The reason for this becomes apparent if we assume the rate of growth from fibre to fibre to vary during the 31 months of the sheep's life. Thus each different length group in the older samples must of necessity contain fibres possessing a common rate of growth rather than a common time of origin, the difference in length caused by different starting points being largely overshadowed by a difference in length caused by different rates of growth. As rate of growth does not affect rate of crimp formation, the mean total number of crimps per fibre for every group tends to be much more nearly constant than in the case of the samples from the young lamb, where the length groups were largely determined by the period of time the fibres had been growing, upon which factor the number of crimps produced also depends In the case of samples of wool from a shorn sheep the former difference is, of course, practically the only one that comes into consideration.

In addition to the considerations cited above there are two other important disturbing influences which must certainly adversely affect the constancy of the mean number of crimps per fibre for different fibre lengths. The first is the effect of sampling errors. Although the samples were taken from the sheep as close together as possible, when 31 samples are considered it is obvious that the cutting of different adjacent groups of fibres for each sample is a very poor approximation to the ideal of studying the same fibres throughout. Recent work by Roberts[2] has shown that fineness may vary within extremely wide limits over relatively very small areas of skin, and there is little doubt that the sampling error with these samples must have been considerable. That such a method did have a serious effect is well

illustrated by the fact that in a few cases the mean number of crimps per fibre was actually found to be *less* in an older sample than in a younger, and the lock correspondingly *shorter*. Secondly, there is the effect of shed fibres and fibres which had ceased to grow. Although such fibres were probably few in number, any there were must have exerted a certain disturbing influence on the regularity of the results obtained.

In view of these numerous and apparently unavoidable sources of possible error the regularity of the data obtained is all the more striking and shows that whereas there is considerable variation in the length of the fibres of a lock, and also in the total number of crimps in each fibre, there is apparently no connection whatever between these two variables

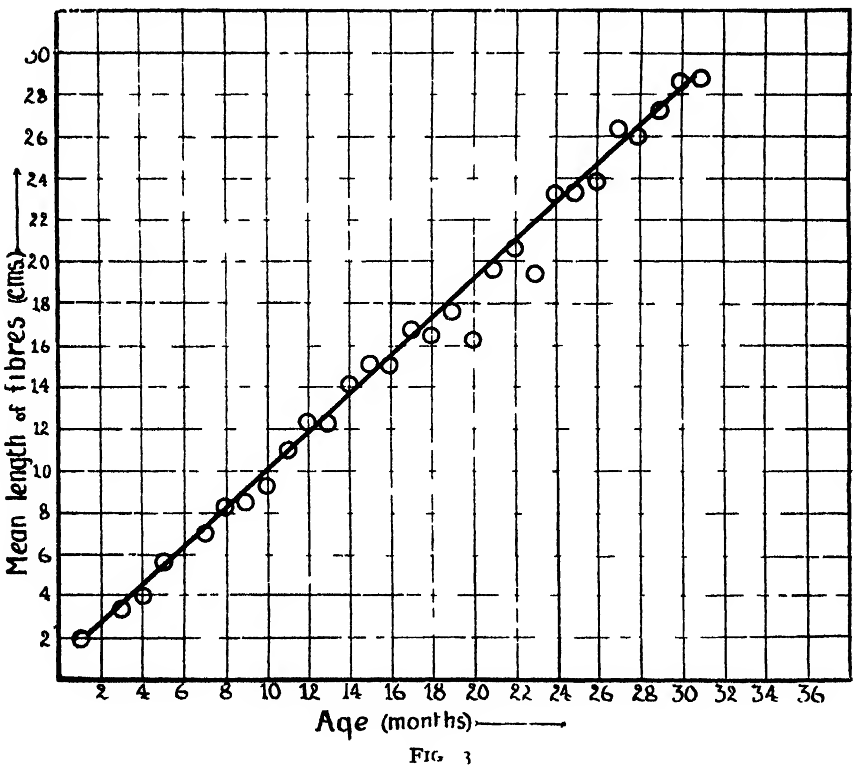


FIG 3

In Fig 3 the mean length of the fibres in each group (calculated from the measurement of the lengths of the 100 fibres taken for the estimation of mean number of crimps per fibre) is plotted against the age of the fibre. Except for the two points at 20 and 23 months respectively, the points all lie about a straight line, indicating a very uniform mean rate of fibre growth during the whole of the sheep's life. Evidence of retarded growth owing to the abnormal length of wool the sheep carried towards the end of its life is lacking. From our point of view it is disappointing that the mean growth rate is so regular. Had the growth rate curve shown definite portions of retarded and of accelerated growth, and had the rate of crimp production at the same time shown the straight line which we have in Fig. 2, further definite support would have been added to our supposition that crimp

production is dependent only upon time, regardless of the rate of fibre growth. Deliberate control of the rate of fibre growth by varying the nutritional conditions of the sheep, and measurement of a similar set of samples from such a sheep, suggests itself as an extension of our investigations.

PART II—VARIATION IN FIBRE THICKNESS ALONG THE LENGTH OF THE FIBRE

Further examination of this unique set of samples of Merino wool from Grootfontein was made by measuring the cross-sectional area at frequent intervals along its length, of each fibre examined for thickness, in order to to determine whether or not seasonal changes had any marked effect on the thickness of the fibre.

Preparation of Fibres

A small lock of fibres was carefully separated from the staple, being drawn out from the tip end, washed in ether, to remove dirt and wool fat, and dried. Individual fibres which appeared to have the tip of the fibre complete were then selected from the clean lock. A tip comparatively straight and free from crimp served to indicate that the tip was not broken off. The selected fibre was carefully withdrawn from the staple by means of forceps having cork pads on their tips. This device served to secure a firm grip on the fibres without damaging them.

As a preliminary investigation two fibres from each third month's sample were examined. These measurements yielded promising results; further fibres were therefore selected and measurements of five selected fibres from eleven samples (taken at bi-monthly intervals from seven months)* were carried out.

Apparatus

The instrument used for the measurements was the fibre rotator, by means of which it is possible to examine a fibre at all points along its length and at the same time examine it completely at any given point by rotating it through 360°. It has been fully described elsewhere.[3] The fibre to be measured was fixed in the chucks and carefully stretched until the crimp was just straightened. Readings were taken at intervals of 1 cm. along the length of the fibre, beginning at the tip end. At each point the fibre was rotated through 180°, its thickness being measured, at intervals of 30°, on its image, which was projected horizontally on to mm. graph paper. From the readings the major (A) and minor (B) axes at each point of examination were determined and the product of these (AB) taken as representing the cross-sectional area, or thickness, of the fibre at that point.

It was found possible to take the readings correct to the nearest mm. of the projected image. The maximum possible error in a reading was, therefore, $\pm$ 0·5 mm. The percentage possible error in the measurement of the major or minor axes depended, of course, on the thickness of the fibre, being greater for fine fibres than for coarser ones. The possible percentage error on the cross sectional area (AB) was, of course, considerably greater than that on the major or minor axis alone. It was calculated that for a typical fibre the greatest possible error on the cross-sectional area was of the order of 40 per cent. At first sight this seems a very high figure, but, apart from the fact that errors of measurement tend to neutralise each other

*Samples less than seven months old at time of cutting were too short for accurate examination.

and therefore such a high percentage error would be extremely unlikely to occur, the actual differences of thickness with which we are dealing are of greater magnitude than could possibly be attributable to experimental error. Thus in the *mean* curve for the longest sample (31 months) the *mean* differences at the maximum points on the curve (taking the minimum point as zero) are 87%, 100%, and 150% respectively. Curves for individual fibres show, of course, still greater differences. Furthermore, the regularities emerging from the results obtained are sufficient to justify the method of measurement.

Presentation of Data

A graph for each fibre measured was constructed by plotting cross-sectional area against the distance from the tip of the fibre. The mean of the results for each set of five fibres (all from the same sample of known age) was then found by calculating the mean thickness of the five fibres at each corresponding point measured along the length, to the nearest square mm. of the measured image. From the resulting figures a mean graph for each sample was constructed.

Table II gives a typical illustration of the kind of measurements that were obtained, and in the last column the calculated mean figures are given,

Table II

Measurement of Cross-sectional Areas of a Set of Five Typical Merino Fibres, all of the same age (31 months), on the Fibre Rotator, at intervals of 1 cm. along the length of each Fibre

Distance from Tip (cms.)	Fibre 1			Fibre 2			Fibre 3			Fibre 4			Fibre 5			Mean AB of Fibres 1–5
	A	B	AB	A	B	AB	A	B	AB	A	B	AB	A	B	AB	
0	7	6	42	6	5	30	6	4	24	7	5	35	5	4	20	30
1	6	6	36	6	5	30	6	5	30	6	6	36	5	4	20	30
2	6	6	36	5	4	20	6	5	30	6	5	30	6	4	24	29
3	6	5	30	5	5	25	5	4	20	6	4	24	4	4	16	23
4	5	4	20	5	4	20	5	4	20	5	4	20	4	3	12	18
5	4	4	16	6	5	30	4	3	12	4	4	16	3	2	6	16
6	6	5	30	7	6	42	6	5	30	6	5	30	6	5	30	32
7	7	5	35	6	5	30	6	6	36	7	5	35	5	4	20	31
8	6	5	30	6	5	30	6	4	24	7	5	35	5	4	20	28
9	7	4	28	6	4	24	6	5	30	7	5	35	6	5	30	29
10	6	5	30	6	5	30	6	5	30	7	5	35	5	5	25	30
11	7	6	42	6	4	24	5	4	20	6	6	36	5	4	20	28
12	5	5	25	5	4	20	5	4	20	6	5	30	5	4	20	23
13	5	5	25	5	4	20	5	4	20	6	5	30	5	3	15	22
14	6	5	30	6	5	30	5	4	20	6	5	30	5	3	15	25
15	6	5	30	6	5	30	5	5	25	6	5	30	5	4	20	27
16	6	6	36	6	5	30	5	5	25	6	5	30	5	4	20	28
17	6	6	36	7	4	28	5	5	25	7	6	42	5	4	20	30
18	7	5	35	6	5	30	6	5	30	8	6	48	6	4	24	33
19	7	6	42	7	5	35	7	5	35	8	7	56	6	5	30	40
20	6	6	36	7	6	42	6	5	30	8	8	64	6	5	30	40
21	7	5	35	8	5	40	6	5	30	8	7	56	6	5	30	38
22	7	6	42	8	5	40	6	5	30	9	6	54	6	5	30	39
23	6	5	30	6	5	30	6	4	24	7	6	42	5	5	25	30
24	7	5	35	6	5	30	6	5	30	6	6	36	5	5	25	·31
25	6	5	30	6	5	30	5	4	20	7	7	49	5	4	20	30
26	6	5	30	6	4	24	5	4	20	6	6	36	5	5	25	27
27	6	5	30	6	5	30	6	5	30	6	6	36	5	4	20	29
28	—	—	—	—	—	—	6	4	24	6	6	36	5	4	20	27

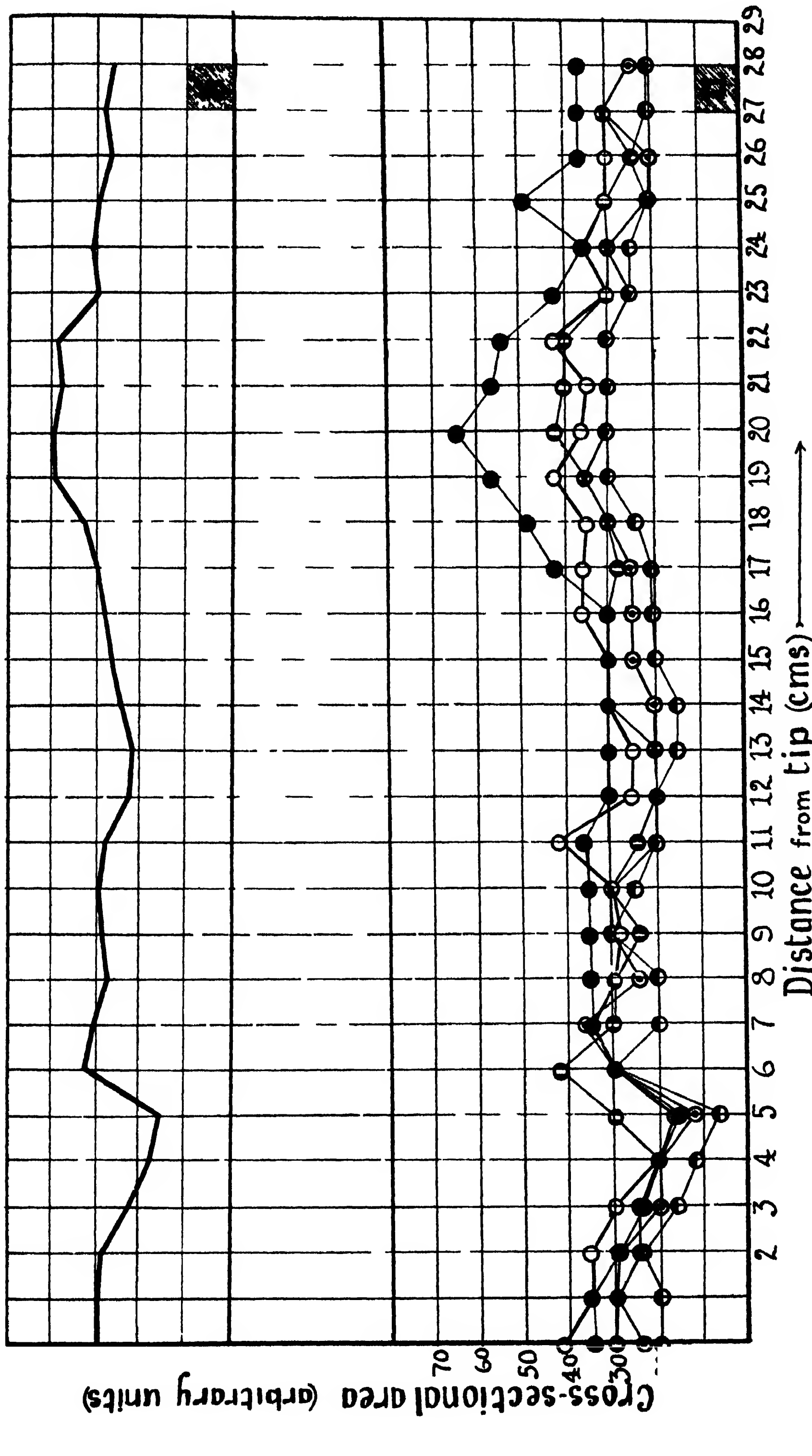

Distance from tip (cms)
2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29
Cross-sectional area (arbitrary units)
70 60 50 40 30

FIG 4

from which the mean curve was constructed. Fig. 4A shows the five curves plotted from the figures of Table II, together with the final mean curve (Fig. 4B) from the figures of the last column.

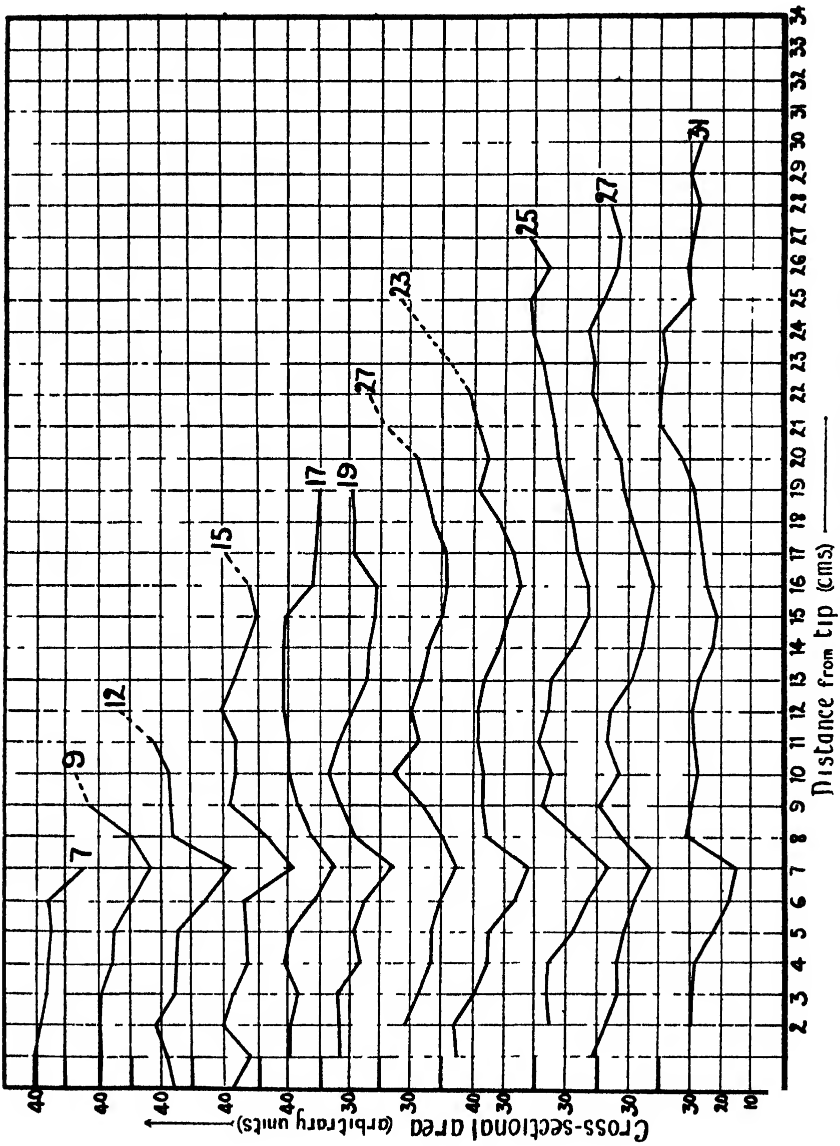


FIG 5—Variation of thickness of fibres along their length
(Numbers indicate age in months)

Results and Conclusions

The final results are presented in graphical form only and appear in Fig. 5. Each curve here presented is the mean curve obtained from the examination of a sample of definite age in the manner described above. In each case the measured variation in cross-sectional area is plotted against distance from the tip, the whole figure thus being composed of a series of figures of the type shown in Fig. 4B, with a common x axis, arranged one above the other to facilitate comparison.

An examination of Fig. 5 at once reveals the striking regularity shown in the variation of fibre thickness along the length for the different samples examined. The most striking common feature of the series of curves is the marked dip which occurs in every case at a distance of 7 cms. from the tip of the fibre. Slightly less marked dips occur at 16 and at 27 cms. from the tip respectively. It will be noticed that in the case of the older fibres it has been assumed that the tip of the fibre was broken or worn off (indicated by the failure of these graphs to extend to the y axis). Visual examination of the fibres supported this assumption, especially in the case of the longer fibres; while handling them it was found that tip ends of 2–3 cms. broke off very easily and many broken tips were found in the distal ends of the longer staples.

There is therefore little room for doubt that with samples over 15 months old it was impossible to find fibres with unworn tips. Allowing for this tip breakage,* which seems perfectly legitimate, the similarity of the type of curve obtained is very remarkable. Thus, roughly speaking, each curve is a reproduction of the one above it but with a new portion, representing the extra length of the older fibre, at the right hand end of the curve. In other words, the older fibres show very clearly in their tip portions the same variations in thickness as the younger fibres do along the whole of their length. These portions of the older and younger fibres were, of course, produced during the same environmental conditions, and the figure shows in a very striking manner the marked effect on fibre thickness which these particular conditions, whatever they may have been, produced on *every* fibre examined.

It will be noticed that in the case of the samples taken at 9, 12, 15, 21, and 23 months respectively, the curves show a sudden upward rise at the extreme right hand end (indicated by the dotted portions of these curves) which is not repeated in the longer curves below them. The explanation of this is simple and lies in the fact that each of the curves in the figure under discussion is a mean curve. In the particular cases mentioned above one, two, or three of the five fibres measured to make the mean curve were longer than the rest and consequently coarser. The extreme right hand portion of these curves represent therefore the mean of only one, two, or three fibres instead of five, and as the longer fibres in question were thicker than the rest the resulting mean curves show a false rise at the end, which did not occur in the curve for the individual fibre or fibres concerned.

In the case of the sample taken at 23 months the mean curve in Fig. 5 represents the mean of the second set of five fibres measured, the first set of five gave somewhat unsatisfactory results owing to the fibres having been chosen from a lock of wool, the tip of which was particularly badly damaged.

Although we have no accurate record of the particular environmental conditions obtaining during the life of the animal with which to compare the fibre thickness curves, it is clear from the figure that the ordinary seasonal changes to which every animal is subject had a marked effect on the fineness of the fibre. Thus, the first sample measured (the top curve in the figure) was seven months old when it was cut on 2nd January 1928, and measured

*Different rates of growth of the fibres concerned would, of course, also affect the position of the marked dip (shown at 7 cms.), but as the mean rate of growth was very nearly the same for each fibre measured (1·0–1·1 cms./month), and we have no means of ascertaining the comparative rates of growth of those portions of the separate fibres that were grown in the first seven months, we have plotted the graphs all on the same horizontal scale, thus assuming comparable rates of growth, but in some cases broken tips.

7 cms. in length. The sample taken the previous October, age five months (which was not measured for fibre thickness), gave an average length of 5·7 cms. During the subsequent two months therefore the wool increased in length by only 1·3 cms. An inspection of Fig. 5 shows that the sharp drop to a minimum at 7 cms. commences in nearly every case at a point 5 or 6 cms. from the tip. In other words the thinning of the fibre corresponds with the slower rate of growth and, moreover, dates approximately from that period of the year (the middle of November), when the good grazing, on which weaned lambs are usually kept, was about exhausted, due to the delayed summer rains of that season. Similarly the sharp rise after the 7 cms. point can be ascribed to the effect of good feeding after the first summer rains.

Subsequent periods of adverse conditions show their effect on the thickness of the fibre in just the same manner. Thus, the maximum thickness of the fibre was reached about a month after the marked thinning shown at the 7 cm. point on the curves. This thickness was maintained with slight fluctuations until about the beginning of August 1928, when the fibres gradually thinned down again, for all the fibres examined which were taken on 22nd October 1928 (at 17 months) showed a decrease in cross-sectional area towards their proximal ends. The minimum was reached about the middle of October, for each of the fibres taken at 19 months showed a tendency to increase in thickness towards their proximal ends, which tendency is clearly reflected in the mean graph of Fig. 5. Again, therefore, increase in cross-sectional area can be said to date approximately from the middle of November. This increase continued until another maximum was reached about April (shown by the graph of the fibres taken at 23 months and subsequently), after which thinning down again occurred and continued gradually until the last sample was taken on the 29th November, after which the animal died. This final thinning is clearly shown in the downward slope at the ends of the graphs representing the samples taken at 25, 27, and 31 months respectively.

Adverse conditions are thus shown to have had a more marked effect on the wool of the lamb than on that of the adult sheep This is what would be expected, for the gradual starvation suffered by the older animal is known to have less effect on the fleece than the sudden change experienced by lambs which exhaust the good grazing given them after weaning.[4]

Hypertrophy and Atrophy

During the examination and measurement of the fibres a very interesting fact emerged which seems to throw some light on the phenomena known as hypertrophy and atrophy. Thus, a change in cross-sectional area was often found to be preceded by what appeared to be a sudden marked increase or conversely a marked decrease, in the diameter of the fibre. However, on rotating the fibre at this particular point it was found in all cases that this sudden change did not represent a real change in thickness so much as a change in *shape* of the cross-section of the fibre. Thus the cross-sectional area of the fibre was approximately the same as that measured at the last point (i.e. a centimetre nearer the tip end of the fibre, but the *ratio* of the major to the minor axis was vastly different. Thus, for example, a fibre measured $6\times5=30$ at a certain point, and at the next point of measurement $9\times3=27$. The change in cross-sectional area (30 to 27) is too small to be noticed on the graph, but the change in the *ratio* between the minor and the major axis is from 1·2 to 3·0. It is therefore not without reason to suppose that the

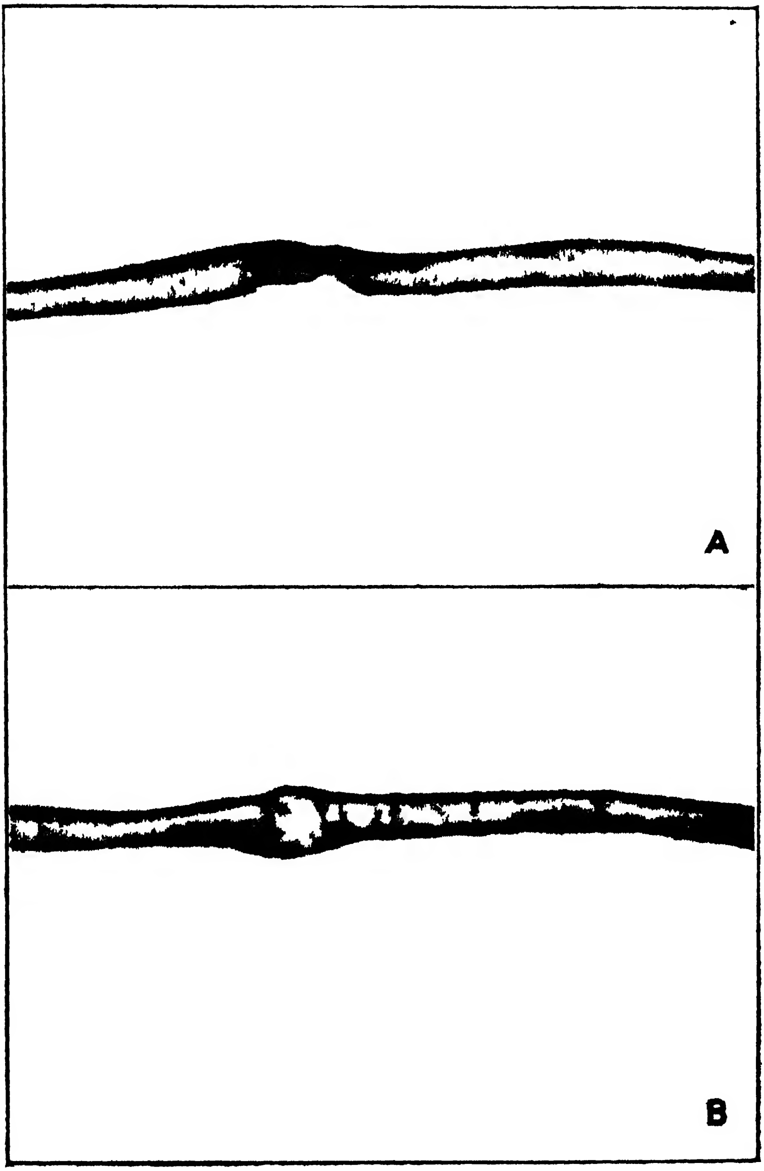


FIG 6—A and B

conditions commonly known as atrophy and hypertrophy may be one and the same, and that instead of an actual thinning or thickening of the fibre all that really takes place is a flattening causing an abnormally thin appearance in one direction and a correspondingly abnormal thick appearance when the fibre is viewed at the same point after having been rotated through 90°. Microscopical examination is limited to the examination of one axis only, and it is not unjustifiable to suppose that had it been possible to rotate the fibre, where cases of so-called atrophy and hypertrophy were observed, as it has been possible to do here, a corresponding thickening or thinning, respectively, would have been observed after rotating the fibre through 90°. This supposition is further supported by the fact that when the minor axis of such a fibre was in view the kink or bend at what appears to be the thin point of the fibre, typical of atrophy, was plainly visible in spite of the slight tension to which the fibre was subjected when under examination.

The phenomena described above is well illustrated by the photographs shown in Fig. 6. Fig. 6A is a photograph of one of the fibres (aged 31 months), from the Merino sheep from which all the samples were taken, actually in position in the fibre rotator. The sudden thinning and slight kink so clearly seen in the fibre are identical with many photographs of wool fibres to be found in the literature representing typical cases of atrophy. Fig. 6B is a photograph of exactly the same portion of the fibre rotated through 90° It can be clearly seen that the spot in Fig. 6A which appeared abnormally thin in Fig. 6B shows an abnormal thickness.

Some Scottish Blackface fibres which were being examined on the fibre rotator for a different purpose showed exactly the same phenomena, and Dry, in Fig. 4 of his recent paper,[5] shows a photomicrograph of a Romney fibre which clearly illustrates the same point, while Fig. 2 of the same paper presumably corresponds to our Fig. 6B.

In conclusion, the authors' thanks are due to Professor J. E. Duerden for so kindly providing the material; to Dr. S. G. Barker, Director of Research, for suggesting the work and the interest with which he has followed it; to Mr. J. A. F. Roberts for helpful discussions during the course of the work; and to Miss D. R. Shaw for her capable and painstaking work in the measurement of crimp and fibre length.

SUMMARY

(1) A unique set of samples of Merino wool, all cut from the same animal at monthly intervals during the whole of its life of 31 months, have been examined for fibre length, number of crimps per fibre, and variation in thickness along the fibre length.

(2) The results support the suggestion that crimp formation is a periodic function of time. No relation is found between the variation in fibre length and that in the number of crimps per fibre.

(3) Measurement of fibre thickness clearly showed the influence of seasonal conditions on the thickness of the fibre, and the variation was remarkably constant in the different fibres measured.

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14—CRIMP IN WOOL AS A PERIODIC FUNCTION OF TIME

III—ANALYSIS OF SOME LOCKS OF NEW ZEALAND ROMNEY AND CORRIEDALE FLEECE WOOLS FOR FIBRE LENGTH AND NUMBER OF CRIMPS PER FIBRE

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Some samples of New Zealand Romney and Corriedale wool showing regular crimp were provided by Mr. D. J. Sidey and were examined in exactly the same way as the previous samples.[1,2]

The results are recorded in Table I and Fig. 1. They are in complete accordance with those obtained previously and show the characteristic line parallel to the x axis when mean number of total crimps per fibre is plotted

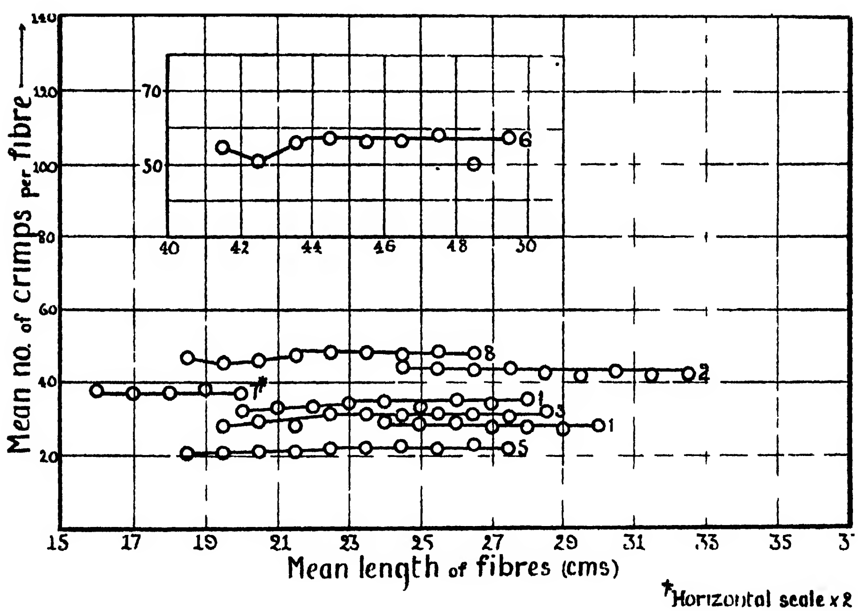

FIG. 1

New Zealand Romney and Corriedale Wools
(The numbers correspond with the numbers of the samples in Table I)

against length of fibre Such a graph indicates the complete independence of fibre length and total number of crimps per fibre rather than a constancy of total number of crimps per fibre in the lock This point may not have been sufficiently stressed in our previous discussions, but is clearly demonstrated if the data be considered in the following way. That the total number of crimps per fibre does vary considerably from fibre to fibre is shown by the figures in column 6. The standard deviation from the mean in these wools lies between 2 and 5. It is therefore possible to arrange the data into groups of fibres, the individual fibres of each group possessing the same number of crimps per fibre but varying fibre lengths. This has been done in the case of sample No. 8 and the figures are collected in Table II. The result is that the mean length of the fibres in the lock appears there as an approximate constant while the number of crimps varies. The standard deviation

(±2·31) from the mean length (22·42 cms.) is almost the same as the standard deviation (±2·22) from the mean number of crimps per fibre (47·4). In other words, it is not that the number of crimps per fibre is constant for all fibres in a lock, but that the extent of the variation is approximately the same within each group of fibres (of the same length) whether they are short or long. That is to say, variation in length of fibre and variation in total number of crimps per fibre are in no way related. Further, from the data we have been able to collect, up to the present, it appears that rate of crimp formation is dependent only upon time and is not affected, as is rate of fibre growth, by external conditions of environment. It would appear probable that each follicle has a characteristic rate of crimp production which remains the same, while the length and thickness of the fibre it produces varies with the condition of the sheep. It is not possible, however, finally completely to establish the truth of this suggestion by making comparisons between different fibres as we have done, although the evidence so obtained seems to point in this direction.

It is proposed to continue the investigation by the examination of single fibres for total number of crimps and mean thickness in order to discover what relationship, if any, exists between crimp and fibre fineness.

Table I

Analysis of Locks of New Zealand Fleece Wools for Fibre Length and Number of Crimps per Fibre

Length* Group (cms.)	*f*	Mean Number of Crimps		M.	S.D.	Coefficient of Variation
		Per fibre	Per cm.			
		(1) Romney Ram (P.)				
23·6–24·5	10	29	1·21			
24·6–25·5	12	28·5	1·14			
25·6–26·5	16	29	1·12			
26·6–27·5	17	28	1·04	27·9	±3·48	12·46%
27·6–28·5	17	28	1·00			
28·6–29·5	17	27	0·93			
29·6–30·5	7	28	0·94			
		(2) Romney Hogget I (P.)				
24·1–25·0	10	44	1·80			
25·1–26·0	12	44	1·73			
26·1–27·0	12	43	1·62			
27·1–28·0	15	44	1·60			
28·1–29·0	10	42·5	1·49	42·6	±2·15	5·05%
29·1–30·0	15	42	1·42			
30·1–31·0	11	43	1·41			
31·1–32·0	5	42	1·33			
32·1–33·0	7	42	1·29			
		(3) Romney Hogget II (P.)				
19·1–20·0	5	28	1·44			
20·1–21·0	5	29	1·42			
21·1–22·0	4	28	1·31			
22·1–23·0	12	31	1·38			
23·1–24·0	16	31	1·32	30·3	±4·23	13·98%
24·1–25·0	15	31	1·27			
25·1–26·0	10	31	1·22			
26·1–27·0	10	31	1·17			
27·1–28·0	13	30	1·09			
28·1–29·0	7	32	1·12			

Table I—*continued*

Length* Group (cms.)	*f*	Mean Number of Crimps Per fibre	Mean Number of Crimps Per cm †	M.‡	S.D.	Coefficient of Variation
			(4) Romney Hogget III			
19·6–20·5	6	32	1·60			
20·6–21·5	5	33	1·57			
21·6–22·5	11	33	1·50			
22·6–23·5	16	34	1·48			
23·6–24·5	10	34·5	1·44		±2·00	5·95%
24·6–25·5	13	33	1·32			
25·6–26·5	16	35	1·35			
26·6–27·5	13	34	1·26			
27·6–28·5	10	35	1·25			
			(5) Romney Hogget IV (P.)			
18·1–19·0	6	21	1·14			
19·1–20·0	10	21	1·08			
20·1–21·0	10	21	1·02			
21·1–22·0	10	21	0·98			
22·1–23·0	13	22	0·98	21·75	±1·80	8·30%
23·1–24·0	13	22	0·94			
24·1–25·0	10	22·5	0·92			
25·1–26·0	10	22	0·87			
26·1–27·0	16	23	0·87			
27·1–28·0	5	22	0·80			
			(6) Romney (Extra Long Lock)			
41·1–42·0	6	54·5	1·31			
42·1–43·0	9	51	1·20			
43·1–44·0	8	56	1·29			
44·1–45·0	9	57	1·28			
45·1–46·0	14	56	1·23	55·0	±5·50	10·00%
46·1–47·0	19	56	1·20			
47·1–48·0	9	58	1·22			
48·1–49·0	6	49·5	1·02			
49·1–50·0	5	57	1·15			
			(7) Corriedale I			
15·6–16·0	8	38	2·41			
16·1–16·5	8	37	2·28			
16·6–17·0	25	37	2·21	37·2	±2·19	5·88%
17·1–17·5	27	38	2·20			
17·6–18·0	27	37	2·08			
			(8) Corriedale II			
18·1–19·0	8	47	2·54			
19·1–20·0	6	45	2·31			
20·1–21·0	13	46	2·24			
21·1–22·0	10	47·5	2·21			
22·1–23·0	22	48	2·13	47·4	±2·22	4·70%
23·1–24·0	20	48	2·04			
24·1–25·0	6	47·5	1·94			
25·1–26·0	7	48	1·88			
26·1–27·0	5	48	1·81			

*Length groups containing less than five fibres omitted

†Per cm. of straightened fibre.

‡Mean number of crimps per fibre, taking into account every fibre measured

(P.) From W. Perry, Masterton, New Zealand.

Table II

No of Crimps per Fibre*	f*	Mean Length of Fibres (cms)	M †	S D	Coefficient of Variation
		(8) Corriedale II			
44	6	20			
45	13	21			
46	17	22			
47	16	22			
48	15	23	22·42	± 2·31	10·30%
49	16	24			
50	5	23			
51	(4)	(25)			
52	6	23			

*Groups containing less than five fibres omitted
†Mean length of fibres taking into account every fibre measured

The author wishes to thank Miss D. R. Shaw for assistance in the counting of crimps and the measurement of fibre lengths.

SUMMARY

Locks of New Zealand Romney and Corriedale fleece wools have been examined for number of crimps per fibre and fibre length. Variation in number of crimps per fibre and in fibre length are found to be in no way related.

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15—THE THERMAL INSULATING PROPERTIES OF FABRICS

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SECTION I—INTRODUCTION

The original object for which fabrics were made was clothing, and this still remains the main use of fabrics. The two principal factors in choosing clothes are appearance and their property of acting as suitable thermal insulators, and hence these are the most important properties of a fabric. Other properties, such as tensile strength, transparency to light, especially ultra-violet, and waterproofness, are usually secondary considerations to most users of fabrics. Appearance, while involving colour and reflecting power which can be measured, has not yet been expressed in physical terms. In thermal insulation, however, we have something which can be measured and expressed, at least comparatively, in physical units.

From very ancient writings, it is clear that the differences in thermal insulation between fabric material have been recognised for many centuries. Linen has always been regarded as cool and wool as warm. This is very easily tested by practical experience, and the result is that most nations have developed a style of clothing suitable for their own climate and for different seasons of the year. Speaking generally, the colder the climate, the greater the weight of clothes worn, but to this there are some very marked exceptions which need not be considered here.

A consideration of heat loss from the skin from the physiological point of view is interesting. In temperate climates the temperature of a human being is generally higher than that of the environment. Heat amounting to 80% of the total produced in the body under normal conditions is lost from the skin mainly by radiation and convection. This heat is replaced by the blood flowing through the skin. The size of the cutaneous vessels is altered to regulate the flow and thus keep the body at an approximately uniform temperature. There are limits to this regulation, and if the loss of heat be too great owing to very low temperature surroundings or absence of suitable clothing, the temperature of the body will fall, causing at first discomfort, then paralysis, and finally death.

On the other hand, if the surroundings are at a higher temperature than the body, convection and radiation are of no use for the removal of heat, although the production of heat is still going on. The evaporation of perspiration, however, is able to remove large quantities of heat, and this is the normal way of preventing excessive rise in temperature.

The general function of clothing is, therefore, to prevent excessive loss of heat from the skin, although in tropical regions it has the opposite use—the prevention of the sun's actinic and thermal radiations from reaching the body. This latter use has been studied by Gregory.[37]

It may be pointed out here that it is not exactly the thermal conductivity which is a measure of the value of the thermal insulation of a fabric. This will be readily seen by consideration of the thermal conditions of a body covered with clothes. Between the skin and the first fabric and between each two successive fabrics there will be air spaces. These spaces may be due to the fact that the garment is not tight, but even if it is uncomfortably tight there is usually a film of air beneath it, caused by the projecting hairs from the skin or the projecting fibres from the fabric. It has been shown that these minute air films have a great thermal insulating value and must therefore be considered.

For the sake of simplicity a simple case may be taken in order to see the factors involved in thermal insulation. Consider a single thickness of fabric covering the skin and separated from it by a layer of air, the whole in surroundings cooler than the skin. There will be heat loss directly from the skin to the surroundings by radiation and convection through the holes in the fabric. The rest of the heat loss will be conveyed across the air space to the inner surface of the fabric, then through the fabric, and finally lost from the outer surface. In all of these transfers, conduction, convection, and radiation will play their parts, but in a different proportion in each case.

It will thus be seen that there is much more than the thermal conductivity of the fabric to be considered. It is quite possible to conceive two fabrics having the same thermal conductivity as measured in the ordinary way, but one having an open structure and the other a close one. The former will allow much greater loss of heat by radiation. Further than this, there is the question of thermal transmission by evaporation and condensation of moisture, which is still further complicated by the wetting of fibres of the fabric.

It will be seen, therefore, that even in the simplest case, heat transfer is complicated. In the work described in this paper the heat flow under equilibrium conditions of this simple case in still air and without movement of moisture will be measured. This may be considered as a first approximation to the measurement of the thermal insulation of a fabric under normal conditions of use.

SECTION II—PREVIOUS WORK ON THERMAL INSULATING PROPERTIES OF FABRICS

Since thermal insulation is one of the most important properties of a fabric there has been, as might be expected, a large amount of work done on this subject.

A thorough search of the literature on this subject reveals a large number of independent researches which are difficult to correlate either in materials or in method of presentation of results. There is little work which takes in a wide enough range of fabrics to draw general conclusions as to the relation between the thermal insulating properties of a fabric and its other physical properties while under test. Some of the work has aimed solely at providing a simple, approximate, comparative test, and this often results in the absence of precautions necessary in thermal measurements. Sensitivity and accuracy are frequently not mentioned, while the effect of such factors as humidity is only vaguely touched upon or completely omitted. These rough methods have, however, a sphere of usefulness.

On the other hand, there are many researches in which the physical side is beyond reproach. Every necessary precaution has been taken and the results are thoroughly reliable. It is unfortunate, however, that with most of this good work, fabrics are only mentioned among many other insulators, or if fabrics are the main interest, the work has been confined to a small range and sometimes to one type of fabric only.

It appears, from a general review of all the work that the thermal insulation of fabrics varies with the weight per unit area and the thickness. The general impression of most workers is that the air enclosed in a fabric has a very important bearing on its insulating properties.

In the consideration of previous work it will be convenient to divide the experimental methods which have been used into four classes—

(1) Methods in which the fabric is held between two plates at different temperatures, and the rate of flow of heat through the fabric is measured. This method gives what is usually called the thermal conductivity of the fabric and may be termed the "disc" method

(2) Methods in which a hot body is wrapped with the fabric and its rate of cooling measured. The outer surface of the fabric is exposed to the air and is not in contact with any solid substance. (Cooling method.)

(3) Methods in which a body is wrapped with the fabric and maintained at a constant temperature by a controlled supply of energy. (Constant temperature method.)

(4) Miscellaneous methods which cannot be put into any of the three above classes.

The papers in each of these classes will be reviewed in the approximate order of publication.

Disc Method

This method, in which the fabric is between two surfaces, gives the thermal conductivity of the fabric under the conditions of experiment. Pressure will be exerted on the fabric and its properties will thus be altered. If the pressure is great in order to get good thermal contact, this change will be large, whereas if the pressure is small, the thermal contact may be so poor that the surface resistance may be comparable with the resistance of the fabric. The values given are therefore the thermal conductivities of a compressed fabric under a pressure which should be stated.

Lees[1] used the "divided bar" method of finding the thermal conductivity of crystals and other substances. He measured the temperatures along the bar, which was of brass, by means of thermo-couples of copper and platinum-silver alloy, in shallow mercury cups. The thermal conductivity of the bar was first found by doing two series of experiments, one to determine the rate of loss of heat from the surface, and the other to determine the distribution of temperature along the bar. He tested several textile fabrics by this method, but the thickness values are only approximate.

Lees and Chorlton (1896)[2] investigated the thermal conductivities of various substances among which were some fabrics. The apparatus, which was designed to be simple and tended to be empirical, consisted of a flat cylindrical vessel measuring 11·4 cms. in diameter and 3 cms. in depth, the

bottom of which was a thick circular plate. In this a radial hole was bored to carry a thermometer. Another plate also with a radial thermometer was hung below this, and between them was the substance to be tested. Steam was passed through the cylinder until the temperature was nearly 100° C. Another thermometer was placed horizontally about 20 cms. below the lower disc to record the temperature of the air approaching it. The surfaces in contact with the material were amalgamated so that if a solid was tested, thermal contact could be established by a thin mercury film. Thickness of the material was obtained by measuring the distance between pegs projecting from edges of the two discs. Steam was passed until the temperature of the lower disc remained constant. From the temperature gradient, the thermal conductivity can be found.

This method was improved later by Lees.[3] This was his disc method and is too well known to call for description. It should be noted that Lees smeared glycerine on his plates to get good thermal contact.

Randolph (1912)[4] used a hot plate 7½ in. in diameter, heated electrically to temperatures from 100° up to 600° C. The cold plate was water-cooled and in two parts, the outer forming a guard ring, always kept within 0·1° C. of the centre portion and without metallic connection to it. Platinum and platinum iridium thermo-couples were used on the two plates, and the heat flow was measured by the rise in temperature of the water stream. His materials were packed together by tapping, then compressed by 25 per cent. He got an accuracy of 2% but a variation between samples of 5 per cent.

Bauer[5] adopted a strange method of measuring the thermal insulation of fabrics. A copper bottle with a flat bottom 5·5 cm. in diameter, whose sides were well insulated, rested on felt on a wooden block. The bottle was provided with a thermometer and contained 200 cc. of water which was heated by steam to 100° C. A thermo-couple (iron-constantan) was then placed under the bottle and a cooling curve determined, readings being taken every two minutes for 90 minutes. This was repeated with the fabric between the bottle and the felt. The ratio of the areas under the curve gave a "heat-protection" number. No relation was found between this number and thickness, specific gravity, nature of material, etc. This method is said to be used at the German Testing Bureau.[6]

Lees' disc method was again used by Emily S. Rood,[7] who corrected for changes in emissivity with temperature which amount to 4–10% change in the results. The discs were 4 cm. diameter and 3 mm. thick, and provided with copper-constantan thermo-couples. Readings were taken when the temperature change was less than 0·05° C. in 15 mins. The temperature differences between the faces of the fabric were 3–9° C. and its temperature 30–40° C. Different values of the conductivity for multiple layers were found due to the drop in temperature between the copper and fabric surfaces. The samples were all dried previously over calcium chloride, which was also in the calorimeter containing the discs. When the drying was omitted a higher value was obtained, showing that increase of regain lowers the conductivity. The thickness was measured to an accuracy of 2% with the samples under a pressure of 6 grm./cm.^{2} The estimated error in the thermal conductivity was 1% for wool and 2% for cotton. The general conclusions were that for woollen materials a loose texture increases the "warmth." For silk the conductivity varies approximately as the density and the order of textiles for warmth is silk, wool, artificial silk, linen, cotton.

At the National Physical Laboratory, Griffiths and Kaye[8] have measured the conductivity of many materials, including fabrics. They do not use a guard ring, as the samples are thin compared with their cross section (45 cm. diam.). The hot face is a copper block heated electrically, the current and applied potential being measured by potentiometer. Two samples, one each side of the block, are used, and the energy passing through the samples was also measured by a water-flow method. The surfaces of the block were amalgamated and flooded with mercury to get good thermal contact. Temperature measurements were by copper-constantan thermo-couples. The heat lost from the edges was calculated from calibration of the instrument with balsa wood. For thick specimens the thickness was measured by micrometer with the sample under a definite pressure. The thin ones were measured in a special apparatus normally used for testing slip gauges. It was found that several thicknesses did not give the sum of the individual thicknesses. The order of accuracy of the method is about 1 per cent.

A very similar method, using a central electrically-heated disc between two samples, was used by Helen Staff.[9] Experiments were made with the sample nearly at room temperature and with various water contents. Approximately linear relations between conductivity and regain and between conductivity and the square of the relative humidity were found. The increase in conductivity for wool for 1% increase in regain is $1{\cdot}7$ to $2{\cdot}0 \times 10^{-6}$ and for cotton, $3{\cdot}9$ to $4{\cdot}0 \times 10^{-6}$ C.G.S. units.

Miller[10] has used this method for the similar problem of the effect of humidity on the various fibrous sheet insulating materials used in building.

More recently Speakman and Chamberlain[11] have refined the disc method by making the cold plate a guard-ringed Bunsen ice calorimeter, while the hot side is a cylinder containing water whose temperature is thermostatically controlled. The thickness of the sample may be measured under test. This method is considered to be among the best of the thermal conductivity measurements.

An apparatus is in use at the Massachusetts Institute of Technology, Cambridge, Mass., U.S.A., consisting of a circular electrically-heated plate with guard ring on one side of the fabric and a water-cooled plate at the other. Temperatures are read by thermo-couples and potentiometer when thermal equilibrium is reached. No published details are known.

Nusselt[12] used a method involving concentric spherical shells, and therefore had to use loose fibres and not fabrics. Similarly with the work of Lamb and Wilson,[13] who used concentric cylinders, fibres were packed into the space between their curved surfaces and ends. While not directly applicable to fabrics these methods are interesting to note in passing.

Cooling Method

This method is perhaps the simplest of all for roughly estimating the thermal insulating properties of a fabric. The apparatus needed is of the kind ready to hand in every laboratory. The ease with which it is applied has probably caused some to use it without due consideration of essential precautions and of the meaning of the results.

This method is employed by Guido Colombo.[14] He heated electrically a closed cylinder, measuring 140 mm. by 50 mm., and filled with mineral oil. This cylinder was suspended by a thermometer inside a perforated metal cylinder 200 mm. by 80 mm. Round this outer cylinder the cloth was

wrapped and the whole apparatus was then placed under a bell-jar at constant temperature. He then measured the time taken to cool through a definite range of temperature. This method is interesting as being the only one in which the fabric was not wrapped directly on the surface of the cylinder.

In 1921, Priestman[15] used a similar method, his apparatus consisting of three copper cylinders with insulating lids. They were 10 in. high and 10 in. in circumference, and each held 1 litre of water. He heated them to boiling point and, by means of a thermometer in the water, read the fall in temperature in one hour. No stirring is mentioned. He found that a thin cloth increased the loss of heat, so he coated the cylinders with thin cashmere, and wrapped the samples over that. In order to compare effects, he left one cylinder bare, covered one with the standard cloth, and on the remaining one he placed the sample to be tested. These were changed to the other cylinders in turn, and the mean results of the tests were taken. The only measure of heat loss given is the fall in temperature, but the temperature of the surrounding atmosphere is not given. Priestman also experimented with the cylinders in a wind tunnel and tried to separate radiation from conduction, but lack of proper units made his efforts practically useless. He does not mention effect of humidity, or thickness and weight of cloths used. An unsuccessful attempt at a constant temperature method was made.

Techoueyres and Walbaum[16] also used this method, but with greater care. They used blackened cylinders equal in dimensions and mass, and holding equal quantities of water. The water was allowed to cool from 40° C. to 30° C. in air at 17° C. The cylinders were then wrapped in a single layer of fabric, and cooling curves obtained. It was found that, in a dry state, silk, cotton, and wool had practically similar effects upon the rate of loss of heat, but that thickness and surface density affected it. Fabrics damped with a salt solution (to represent artificial perspiration) were tested. Wool showed little change, but silk and cotton had a much greater loss of heat.

The only results given are curves without experimental points marked, and no experimental details are given.

Bachmann[17] used the Hill Katathermometer,[18,19] an alcohol thermometer with a bulb of 22·6 square cms. surface area. He measured the time taken for its temperature to fall from 38° C.–35° C. From this and the constant of the instrument was found the loss in heat per square cm. in mgm.-calories per second. The fabric to be tested was wrapped round the thermometer, and times of cooling noted. It was found that for results of any value the sample must be at the same temperature as the thermometer at the start of the experiment. Other improvements would be a larger surface area, and longer time of cooling. Bachmann found that very thin samples allowed greater loss of heat than the naked instrument. This, however, was shown to be the effect of difference in temperature between the sample and the Katathermometer.

Another instrument embodying the improvements already mentioned, together with a different range of temperature, has been constructed.

Before they heard of the work of Techoueyres and Walbaum, Dantzer and Roehrich[20] used a blackened brass cylinder filled with hot water and suspended in a glass vessel to prevent cooling by draughts. The air temperature was 25° C., and cooling was timed from 50° C. to 40° C.; times for 45° C.

and 42° C. were also taken. The flannel, 700 square cms. in area, was round the cylinder, while the base was insulated by a circle of eiderdown. Experiments were performed with moist and dry cloths. The conclusion reached was that a flannel to be warm should be well raised and not merely a web of wool. Moist cloths were found to give greater apparent heat transmission, owing to evaporation.

Wagner[21] reports some work of Stonawski, using the cooling method of a fabric-jacketed brass cylinder for ten fabrics. He attributes the method to Muller but gives no details or references. The only work by Muller which can be found employs the constant temperature method.

A somewhat similar method to that of Dantzer and Roehrich was used by Schofield,[22] who coated a calorimeter with the fabric to be tested. This was placed inside a larger vessel surrounded by water to keep the temperature constant.

The results of all these experiments are given as times of cooling, and apply only to the apparatus and temperature used. They cannot, therefore, be compared to any advantage. It may be remarked here that experiments with damp cloth may lead to erroneous results, owing to the absorption of the latent heat of water evaporated.

Constant Temperature Method

This method has been used in work which may be considered the best of any yet done on the thermal insulation of fabrics. The chief advantage lies in the fact that the measurements of heat are replaced by those of electrical energy, and can, therefore, be made more easily and more accurately.

Haven,[23] in his early experiments, used the cooling method to test the relative warmth of cotton and wool blankets. His first method was to measure the rate of cooling of iron pipes, 60 in. long and 4 in. in diameter, containing water and wrapped in the various blankets under test. Later he used a constant temperature method, the heat lost being made up by electric heaters, which were switched on and off by a mercury thermostat.

The heaters were in a copper tube 60 in. long and 4½ in. in diameter; the remaining space was filled with water, and the ends of the tube were capped with a thermal insulator to prevent end losses. The thermostat and a thermometer were inserted in side tubes in the centre of the main tube, involving the cutting of holes in the specimen blanket. The blankets, under constant tension, were wound round the cylinder three times and sewn down. The current and voltage were read every 30 seconds, and the times of operation of the thermostatic relay noted. The results are claimed to be accurate to four significant figures. Thickness measurements were made by a micrometer and plate with electric contacts. The conclusion reached was that a well-napped cotton blanket was nearly as warm as a woollen blanket of the same thickness, the main part of the insulation being due to the air enmeshed in the blanket.

Further experiments performed by the Bureau of Standards[24,25,26,27] embodied the same principle as that of Haven, but the heater was a square plate, 1,000 square cms. in area, with a surrounding guard ring. It was heated electrically from below, and thermo-couples were provided at many places for measuring the temperature, and the difference in temperature

between the plate and the guard ring. The whole heater was set in a wooden board, and another similar one mounted in the other face to prevent heat flow through the board. Energy and temperature measurements were made by potentiometer. The fabric was stretched over the plate at constant tension by passing it over rollers at the edges and attaching weights. The thickness was measured by thrusting a needle of known length through the fabric and measuring the excess length. The tests were carried out in a room at 70° F. and 65% R. H. The various currents were controlled and equilibrium was reached in about 1½ hours. Independent tests agree to within 1 per cent. Further experiments showed that cotton sheeting placed above the blanket increased the thermal resistance, especially when the blanket had a loose weave and high nap. This was taken as an indication of the high value of enmeshed air in thermal insulating media

Next, the effect of laundering upon the thermal resistance was investigated. In a washing machine of the cylinder type, washing with soapy water proceeded for ten minutes, and then rinsing for two minutes. Surplus moisture was extracted, and the blankets dried on frames and renapped.

Tests were made on the new blankets, which were then washed. A second test was made, and then the blankets were renapped and tested a third time. One blanket was washed and renapped four times. It was found that washing lowered the thermal resistance, whilst renapping increased it again to its former value. Shrinkage increased the resistance by thickening the blanket.

A rather different method was employed by Floyd and Baker.[28] They used a copper cylinder, 4 in. long and 2 in. in diameter, which was filled with oil and heated electrically. The oil was stirred, but no correction was made for the energy imparted. The cylinder was covered with the fabric, but the top and neck of the cylinder and the leads were left uncovered. The cylinder was suspended inside a water-jacketed cylinder, the water being stirred, and the air in the annular space was kept in slow circulation by a small fan. Mercury thermometers showed room, water, air, and oil temperatures. Current and P. D. were measured with and without the fabric, which formed a cap on the cylinder. The "protective ratio" is the ratio of the watts supplied in the two cases. These investigators noted the humidity of the air. Expressed as a percentage, the saving in energy divided by the energy used by the bare cylinder was called the "protective value." The "protective ratio" was found to be constant between 5° and 35° when the air was dry, but low regain gave it a high value. For flannels it was found to depend on whether the nap was inside or out.

Muller[28] has used the Davos frigorimeter, which consists of a blackened copper sphere of 176·7 square cms. surface area, in the investigation of the thermal insulating properties of stocking fabrics. The sphere was mounted on a plate by means of a metal tube containing a specially constructed "contact thermometer." The sphere was heated electrically to 33° C., and the temperature was kept constant by the "contact thermometer." A special clock showed the time during which current was supplied. The thermal properties of a number of stocking fabrics were examined in the neighbourhood of 8° C., and in still and moving air, by covering the sphere with the material to be examined, and installing the apparatus in a double-doored ice box. From the results it appears that in still air more heat was given off when the sphere was covered with ladies' stocking than when it

was bare. In moving air, the same material retained a small amount of heat, which, however, is much less than that retained by men's stocking fabric.

Freedman[30] used a cylinder containing a heating element and covered with the fabric to be tested. This cylinder was placed in an air duct whose temperature was altered by means of a refrigerator. A motor-driven blower kept the air circulating at desired velocities. By means of a xylene thermometer and electrical contacts, the temperature of the cylinder was kept at some point between 90° and 100° F., while the duct temperature could be varied from 20° F. upwards. For a given wind velocity and duct temperature, the electric current was varied until a steady temperature difference was reached, and then the energy required was taken as a measure of the thermal conductivity of the fabric. Wool, wool and cotton, and cotton fabrics were tested, besides some Alaska seal peltry. The fur had the greatest heat-retaining power in both still air and winds, and wool proved to be a better insulator than cotton on the whole.

Again, owing to the differences in the method of expression of the results, a comparison cannot be given.

Other Methods

Some methods which do not come in any of these three classes are detailed below. While some have not to be used for fabrics, they would apply if necessary, and are included to give an idea of the many methods available.

Heat insulators were tested for efficiency by Thomas,[31] who used a copper can 8 cm. in diameter and 10 cm. high. Two holes were bored diametrically in its curved surface, and into them were fitted rubber stoppers which held in position a copper tube of 19 mm. internal diameter. Rubber stoppers which closed the ends of this tube held in position another tube of external diameter 12·2 mm. Superheated steam was passed through the inner tube, the annular space between the tubes being packed with the insulator under test. The rise in temperature of a known weight of water, contained in the can, was noted during a definite interval of time. The can was lagged with asbestos to prevent outside heating from waste steam. Thomas found that thickness of insulator compared with diameter of inner tube affected heat loss enormously. He used such insulators as magnesium, kieselguhr, and asbestos fibre, and gave his results in tables and graphs.

Experiments on the comparison of woollen and cotton blankets as heat insulators were performed by Lewis.[32,33] He used cork test boxes 12 in. square, and heated them by electricity, the heaters being shielded with black cardboard. Two boxes were used simultaneously for purposes of comparison. The blankets covered the open tops of the boxes and were weighted evenly at the ends. He had voltmeters and ammeters in the circuit, and thus measured the energy input. The woollen blankets were found to be warmer than the cotton ones, but weight for weight one cotton blanket gave better results than the woollen ones. The effect of washing and of humidity was to lower the retentive power of all the blankets, but as the wool fibre is springy, the effect of washing on the woollen blanket was not nearly so drastic as on the cotton one. At 100% relative humidity the cotton and woollen blankets gave approximately the same results.

A somewhat similar method has been used by Centmaier,[34] the fabric being clamped between two "pots," one containing a source of heat and the other a thermometer.

Rubber treated with various pigments was tested by Williams[35] for conductivity and diffusivity. He used a thin copper cylinder 4 in. in diameter and 5 in. high. This he coated with the substance under test. Steam, previously dried but not superheated, was passed in by a tube reaching nearly to the bottom of the cylinder, and the outlet had a baffle plate just below it to prevent water running back. A thermo-couple was introduced in a capillary tube and recorded the temperature. The whole apparatus was totally immersed in a constant temperature bath, and the weight and thickness of the substance under test were measured. The method for finding diffusivity consisted in rolling a sheet of the material in the form of a cylinder. The outside was kept at constant temperature by coating the cylinders with aluminium foil and immersing them in boiling water, and the temperature at the centre was recorded by a thermocouple fastened on the inside edge of the roll. Graphs and tables of results are given, together with an equation connecting conductivity and diffusivity. The cell method is considered to be more accurate, but the roll method more convenient.

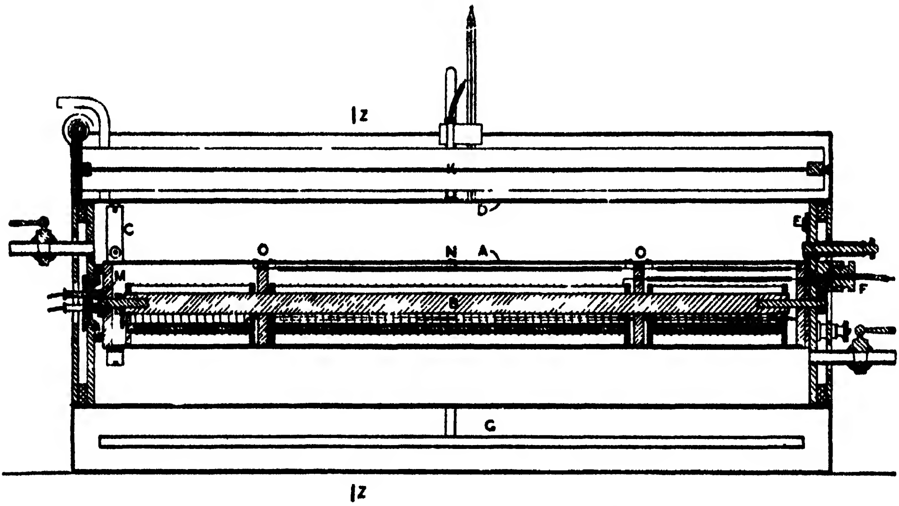


FIG. 1A

The Fabrics Co-ordinating Research Committee[36] has found that the wearing of a light mackintosh over soaked clothing greatly reduced rate of loss of heat from the body.

Tropical clothing has been tested for transmission and reflection of radiant heat by Gregory,[37] who used, as a source of radiant heat, a furnace supplied with current from an accumulator. The fabric was wound round two rollers, so that successive portions might be tested. About 8 square cms. were tested at once, the heat transmitted or reflected being measured by a Moll thermopile. By sewing strips of different fabrics together, they could be tested under the same conditions. Between the strips were placed pieces of paper, having 2 in. squares cut from them in order that the total radiation might be measured without disturbing the fabric. Graphs are given showing the amount of heat reflected or transmitted at different angles.

The effect of humidity was also investigated. The test chamber was dried for five days with phosphorus pentoxide, and then the air was conditioned by being passed over sulphuric acid solutions giving the desired humidity. High humidity gives less heat transmission, but only affects

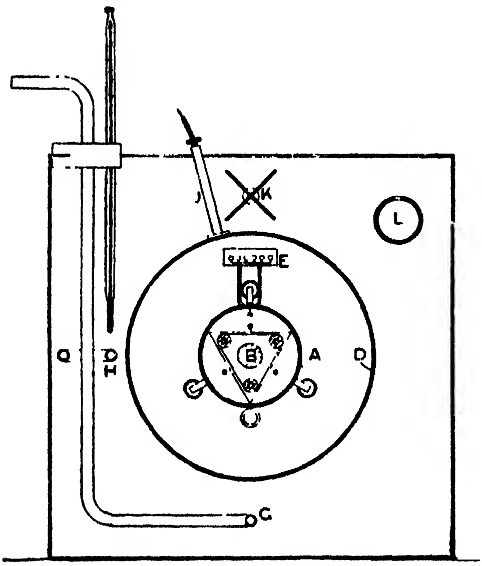
reflection very slightly. Washing was found to increase transmission, due to the removal of filling.

A recent paper[38] by the same worker, gives particulars of another apparatus which measures the reflected, transmitted, and absorbed radiant heat by water flow methods, using a gas-filled electric lamp as a source of heat. Reflection varied from 60% to 40%, while transmitted ranges from 5% to 44 per cent.

In order to test the effect of the colour of materials on the loss of heat from the body, Skowronski[39] made a series of experiments by means of the "thermoscope galvanometer," Hill's Katathermometer, and Stephan's calorimeter. He used linen, aniline dyes, and chinese ink. He describes minutely the methods employed, and furnishes graphs and tables. He arrived at the conclusion that the natural pigment of clothing materials does not have any effect on the loss of heat from the body, but that when aniline dyes are used there is a reduction in the transmission of heat. In further investigations he found that linen dyed with aniline black or chinese ink was the worst conductor of heat, and that this did not depend on the blackness but on the pigment.

EXPERIMENTAL

It was thought necessary to test the fabrics for heat insulation under conditions approximating as nearly as possible to those obtaining in actual use, and with this end in view previous methods were considered. At length, the cylindrical type of heater, similar to that employed by Haven but with guard rings was adopted as this body is most easily covered without deformation of the fabric. The constant temperature method was chosen as being more reliable than cooling or other methods, energy being supplied from large capacity accumulators. In this way the measurements were practically all electrical, and could be obtained with greater accuracy than is possible with measurements of heat.



Cross-section at ZZ Fig. 1a.
FIG. 1B

The "heater" (A, Figs. 1A and 1B) consists essentially of a copper tube containing windings of resistance wire. The tube has a diameter of about 5·5 cms., and the central portion is 25·0 cms., while the guard ring at each end is 10 cms. long.

Two discs of red vulcanised fibre insulate the end tubes from the central one electrically, and, to some extent, thermally. Two similar discs close the ends, and are drawn together at their centres by screws projecting from the ends of a rod of vulcanised fibre B, thus clamping the whole "heater" together solidly.

The surface of the "heater" was thoroughly cleaned and coated with shellac varnish, which is non-tarnishing and easily reproduced.

On the central rod are supported the three heating coils, made of Eureka wire wound on quartz insulators The resistance of the central coil is about 6 ohms, and that of the guard ring coils about 10 ohms.

The leads to these coils are heavy copper wires insulated with glass tubing. These leads end in three terminals at the front of the tube, while the "common return" is soldered to a plate at the other end.

The thermo-couple N, which eliminates the need for a mercury thermometer, was placed at the central point of the tube, while the cold junction is on the outer tube. In the same radial plane differential thermo-couples OO are provided between the central and end tubes. The thermo-couple leads are all carried inside the tube, and insulated and protected from injury by glass tubing.

The far end of the heater is supported by a three-legged spider C, which is clamped round it by three screws. The legs are provided with rubber rollers, which prevent scratching of the inner surface of the outer tube.

The ends of the outer tube were closed to prevent draughts by two Monel-metal "plates." Each plate consisted of two discs between which a rubber ring of the same outside diameter is held. In each of the "plates" is a large tap to allow air to be circulated in the annular space between the heater and outer tube. One plate is attached to the heater. Leads for the heating currents and thermo-couples pass through this plate. The terminals which take the current through the plate are insulated by a special rubber air-tight joint The plate at the other end of the apparatus has a central insulating bush for three spring contacts, which impinge on the plate M on the "heater."

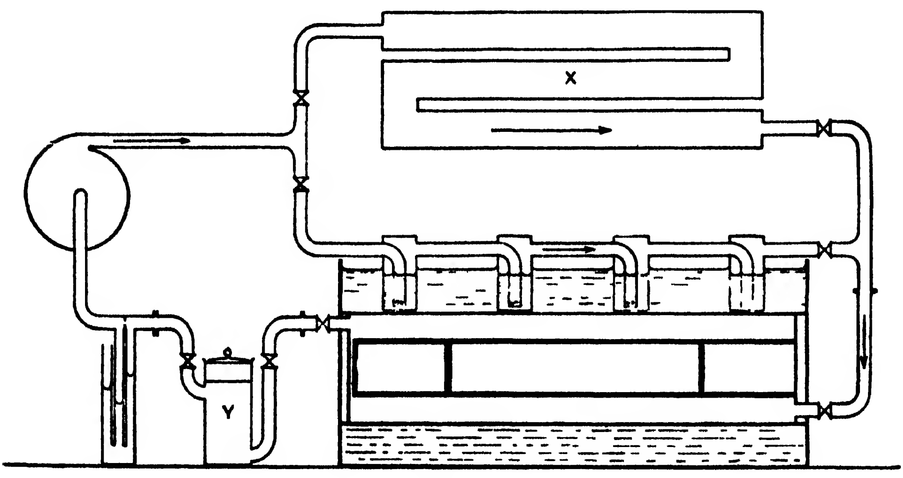


FIG 2

Surroundings

The outer tube D is built into a tank which can contain water. This is stirred and circulated by the long paddle K, which is driven by an electric motor through a worm gear. The inside surface of the outer tube was blackened to obtain an untarnishable and enduring surface. Water from the mains is supplied by a pipe G, perforated with holes and running along

the bottom of the tank. A large tube L with many holes prevents overflowing, and a drain tap is provided. An independent cooling or heating system H runs the whole length of the tank.

An air circulation system is provided for changing the humidity (Fig. 2). A small centrifugal fan pumps air through the wetting or drying system to the chamber round the "heater," through a sample bottle containing clippings of the material under test, and then through a combined flowmeter and manometer. The pressure inside the chamber is always kept rather above atmospheric, so that leaks are outwards. The only possible inward leak is through the fan bearings, and all air entering this way has to pass through the drying or wetting system before reaching the experimental chamber.

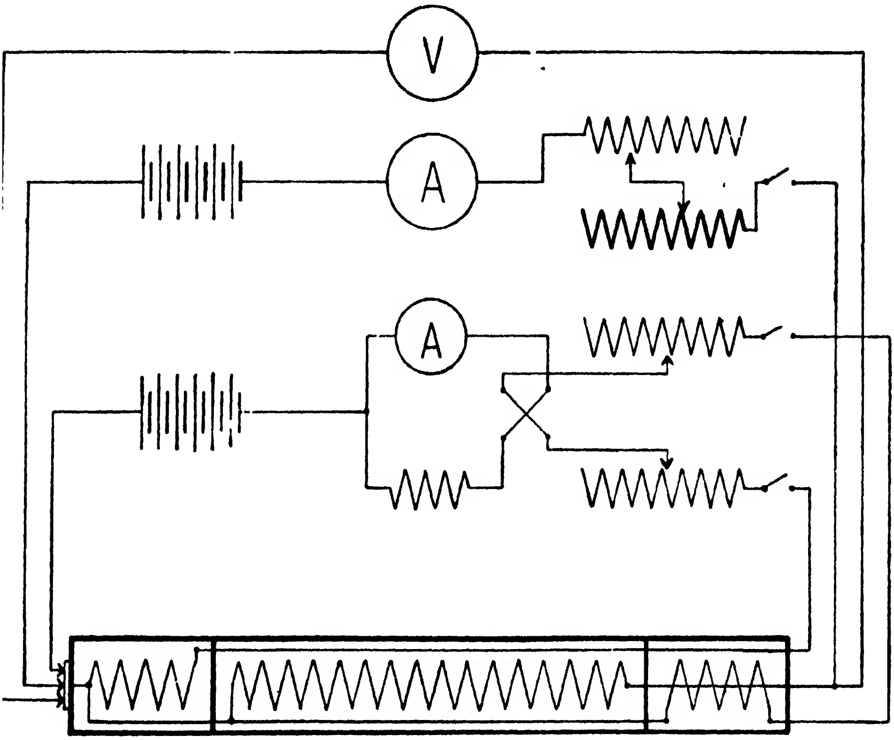


FIG. 3

The drying system consists of several calcium chloride tubes, while the wetting system is a number of wash-bottles immersed in the water in the tank. By weighing the sample bottle and contents from time to time, the hygroscopic state of the fabric under test could be estimated.

At first the fabrics were made into sleeves fitting directly on to the "heater," but later a definite air film was created beneath the fabric, by using woven wire frames of open mesh and fine gauge. One frame fitted closely on the "heater," but the second and third measured 6·5 cms. and 8·0 cms. in diameter respectively, and held the fabric completely clear of the "heater" surface.

Energy Control and Measurement

In order to get a very steady current for the heating coils, large capacity accumulators were used. It was quickly found that variations in the guard ring circuit influenced the main circuit, and so a separate battery was provided for the guard-ring "heaters." The circuits for the last mentioned were next separated, except for the common wire inside the "heater."

Three spring contacts in the end-plate serve for the main heater circuit, guard ring heaters circuit, and voltmeter lead respectively. These contacts keep the circuits separate and make control easier. The currents are controlled by ordinary rheostats, the central portions being also provided with a carbon compression resistance for very fine adjustment.

The complete electrical circuit is shown in Fig. 3.

Temperature Measurement

The temperature differences between inner and outer tubes, and between the central and guard ring parts of the heater were measured by the thermocouples already mentioned. The temperature of the bath was measured by an N.P.L. certificated thermometer.

As the temperature of the water in the tank varied, a large quantity of water in a Dewar flask was used during the experiment to get a steady temperature. Then the circuit was changed by the mercury switch, and the difference in temperature between the outer surface of the outer tube, and the heater surface, was measured. Two mirror galvanometers were used in circuits, as shown in Fig 4.

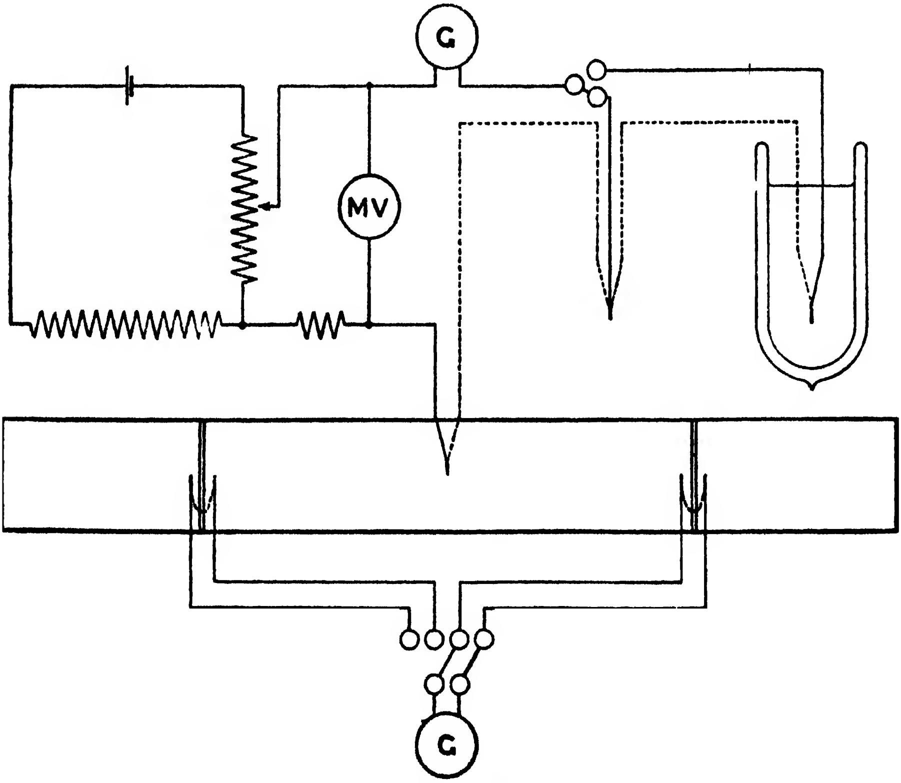


FIG. 4

Method of Experiment

The sleeve is placed on the "heater," the spider is screwed in position, and the whole put in place. When the tank is full of water in circulation, the heating currents are switched on and carefully adjusted until a constant temperature very near the one desired is reached. When balance is obtained the mercury switch is operated, and the temperature difference is measured.

Measurements of Properties of the Fabrics

Material—Where fabrics have consisted of more than one type of material they have been submitted to the tests of the Bradford Conditioning House. These give the proportions of the various fibres calculated on the clean dry weight.

Colour—No measurements of colour have been carried out. Any descriptions given are purely by visual judgment.

Weight per Unit Area—Squares were cut out by a sharp knife and weighed in the constant humidity-room after conditioning for several days.

Thickness—An instrument was designed capable of measuring the thickness of a fabric under definite pressures, which varied from 1 mgm. to 100 gms. per square cm. Thicknesses could be measured to 0·01 mm.[40]

Percentage Hole Area—This property was measured by the use of an adaptation of the photo-electric method of yarn levelness measurement, employed by Barker and Stanbury.[41]

Permeability to air—The method of measurement has been described in a recent paper.[42]

SECTION IV—RESULTS AND CONCLUSIONS

It has already been pointed out that the thermal insulating properties of fabrics are not expressed by the thermal conductivity. A new quantity depending only on the heat lost by the heater uncovered and covered by the fabric *in a definite specified way* has, therefore, been defined. This quantity, called the thermal insulating value (T.I.V.), is—

$$\left\{1 - \frac{\text{Heat lost by covered heater}}{\text{Heat lost by uncovered heater}}\right\} \times 100 \text{ per cent.}$$

To see its meaning, certain cases may be considered. If the heat loss were the same with as without the fabric, the T.I.V. would be zero. But if no heat were lost its value would be 100. Some thin fabrics placed directly on the heater cause a greater emission of heat than with the bare cylinder. In this case the T.I.V. is negative. This occurrence may appear strange, but it is readily understood when it is remembered that the effective surface is greatly increased when the smooth varnished surface is covered by a fabric.

Before comparison of fabrics could be undertaken it was necessary to determine the effect of each of the various conditions under which comparison could be made. It was then possible to specify in detail the conditions under which the fabrics should be compared.

The first experiments were to find the relation between the energy supplied (i.e. total heat loss), and the difference of temperature between the surface of the heater and the outer tube. Four series of observations were taken—

(A) Heater uncovered—outer tube unblackened on inside.
(B) Heater uncovered—outer tube blackened on inside.
(C) Fabric wrapped directly on heater—outer tube blackened on inside.
(D) Fabric on 6.5 cm. frame—outer tube blackened on inside.

The results are shown plotted in Fig. 5. It will be noticed that the curves do not differ greatly from straight lines. This allows experiments to be done at temperature differences approximating to a selected standard and the corrections simply calculated.

From the curves it may also be deduced that the ratio of the ordinates of any two curves is practically independent of temperature. It is therefore possible to select any convenient temperature for the comparison of fabrics.

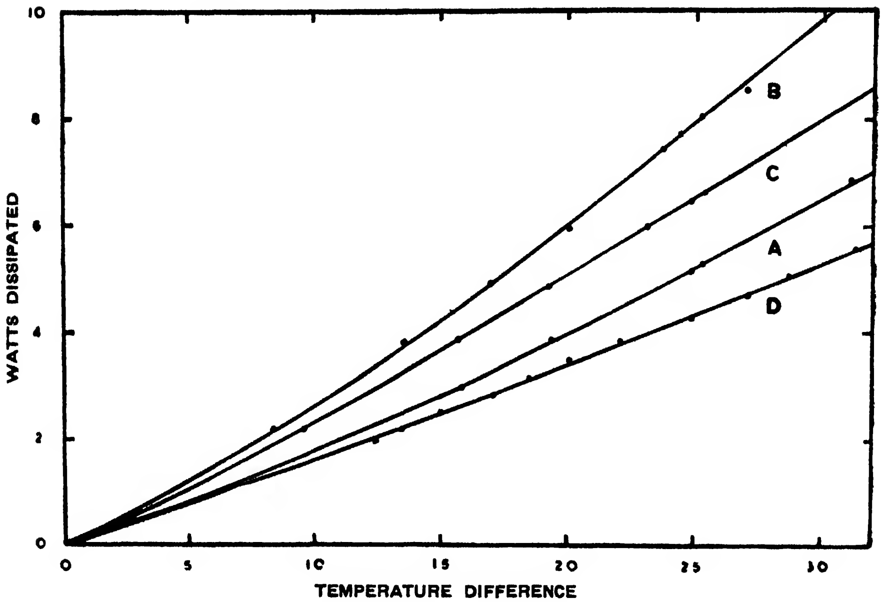


FIG. 5

Very large changes of humidity, such as would not be met in normal practice, were tried. These were produced by the continual passage of the air through the wetting system, so that it became saturated at a temperature just lower than that of the cold surface, or by passage of the air over the calcium chloride. They had very little effect on the total heat loss and it was concluded that the differences due to ordinary changes of humidity are less than the experimental errors, so that measurements could be made without the need for humidity control. This result appears to contradict results of previous workers, but it must be emphasised that in most of these investigations the fabric has not been left for two or three days in the experimental condition to reach hygroscopic equilibrium as it was in the present experiments. Gregory, who was careful to allow his cloth to reach equilibrium, found a small decrease in transmitted radiant heat with increase of humidity.

In all the earlier experiments the fabrics, made up into sleeves, were on the surface of the heater itself. The sleeves were made so that they slipped on and off readily without being slack. No special precautions were taken

to make them all fit in exactly the same way, as it was thought that the fitting would have very little effect on the surface density. With these sleeves, thermal insulation values could be repeated consistently to 1%, and numerous tests were made in this way.

The effects of multiple layers and combinations of fabrics were being tried when certain anomalies were discovered in the results. After many experiments and the elimination of all possible variables and complications, it was found that, while any sleeve gave results consistently, two sleeves of the same knitted material gave very different results. The two sleeves were closely examined and tested for weight per unit area, and no differences capable of explaining the discrepancies were found. It was noticed, however, that one sleeve was more slack than the other on the heater, it gave a much higher insulating value, but when it was tightened the value fell eventually to below that for the other sleeve.

As these results were for a knitted fabric which is easily stretched, it was decided to test woven fabrics, and a flannel and a blanket were chosen. The same effect was again obtained as is seen in the table—

Effect of Tension of Fabric on Thermal Insulation

Description	Thermal Insulating Value Tension increasing		
Hosiery (wool) ..	10·5	—3·5	-6·1
Flannel	10·5	5·0	2·9
Blanket	40·7	31·2	-

It is thus very clearly established that it is very important in comparing fabrics either to find a standard or comparative tension for each fabric and work to that, or to eliminate the effect of tension completely.

Since in the above cases the stretching was never more than a few per cent. of the original length (say 3% to 7%), the fall in insulating value cannot be explained by changes of surface density, or the opening of the interstices of the fabric, so as to allow a freer passage of air. The only possible explanation appears to be that a fabric resting on a surface ordinarily is supported by the more projecting fibres, and that an air film, which is comparable in its insulating power to the fabric itself, exists between the fabric and the surface. When the fabric is tightened on to a curved surface this film is diminished in thickness, and the fabric establishes a better thermal contact with the surface, and thus the apparent thermal insulation is diminished.

This suggestion was tested out as follows. A more definite air film between the fabric and the heater was created by the insertion of the very open-mesh wire gauze. This gave a much greater insulating value, but there was still a large difference on the fabrics being stretched. It was noticed that it was still possible for the fabric to sag through the meshes and come into contact with the heater.

The two larger frames of wire netting of different diameters were then tried, and further increase in the insulating value of the fabrics on these was found in all cases. But now that the fabric, whether stretched or loose,

was quite clear of the heater surface, it was found that the insulating value was unchanged on the fabrics being tightened on the frame. This result gave a method of comparison of fabrics independent of tension within the accuracy of experiment. In all previous work the effect of this air film beneath the fabric has been completely overlooked. The results are, therefore, open to very grave criticism, as the effect must have occurred in all work involving the wrapping of a body in the fabric. It further confirms all that has been said above as to the methods involving the compression of the fabric between two surfaces. Once this effect has been seen it becomes quite obvious, and it is remarkable that it should not have been detected before. Clearly, therefore, a fabric must be measured with both surfaces free from solid bodies as far as possible. This condition was approached by the supporting of the fabric on the very open wire frame, 6·5 cm. in diameter, for all comparative measurements.

COMPARISON OF DIFFERENT FABRICS

From the results given above it is now possible to formulate a scheme for the comparison of different fabrics under defined conditions. It was decided to make the comparisons on the 6·5 cm. frame, and at a standard temperature-difference of 25° C. approximately, the values being corrected to 25·0° C., while the cold temperature was kept as near as possible to 12° C. The thermal insulating value of all fabrics was measured under these conditions.

The results, with particulars of the fabrics and other measurements made on them, are given in the following tables—

Description	Sample No	Weave	Weight (in gms per 100 sq cms.)	Thickness in mms at pressure of 10 gms. per sq cm	Light* Transmission %	Permeability to air (in ccs. per sq. cm for 1 cm. of water)	T.I V. %	Remarks
Woollen suiting	98	2 × 2 H.B	2·72	0·84	...	62·5	37·4	14/15 oz.
" "	100	2 × 2 Twill	3·38	0·92	...	38·9	37·1	17 oz.
" "	109	2 × 2 Twill	4·93	1·02	...	10·1	37·6	21 oz.
" "	111	2 × 2 Twill	3·47	0·69	...	6·0	35·4	16 oz.
" "	112	2 × 2 Twill	2·62	0·56	...	12·4	35·1	12/13 oz.
" "	113	Common Twill	3·84	1·27	...	25·4	38·8	19/20 oz.
" "	115	Bell Celtic	3·24	1·27	...	64·9	40·8	15/16 oz.
" "	116	Common Twill	2·57	1·07	...	77·0	37·0	13/14 oz.
" "	117	Herringbone	2·57	0·89	...	119	36·0	15/16 oz.
" "	122	Common Twill	5·30	1·70	...	26·2	41·4	21/22 oz.
" "	118	14 L.D.C. (backed)	6·58	2·88	...	20·2	46·5	32 oz.
" "	119	16 L D.C.	6·70	1·57	...	5·9	38·9	27 28 oz.
" "	29	2 × 2 Twill	4·21	1·60	...	42·5	40·4	...
" "	31	2 × 2 Twill	5·33	1·50	...	15·6	40·4	...
" "	106	2 × 2 Twill	4·07	1·52	...	44·2	39·7	17 oz.
" "	107	2 × 2 Twill	5·10	1·73	...	17·8	41·0	24 oz.
" "	108	2 × 2 Twill	3·56	1·07	...	27·3	38·2	15 16 oz.
" "	110	2 × 2 Twill	2·66	0·74	...	18·2	40·6	13 14 oz.
" "	114	Common Twill	4·41	1·14	...	25·8	37·1	22/23 oz.
" "	120	Common Twill	5·47	1·62	...	5·5	40·1	27/28 oz
" "	121	Common Twill	2·92	1·30	...	21·0	41·4	13 14 oz
" "	147	Effect on 2 × 2 Twill base ...	2·92	1·80	4·2	285	44·1	...

*Where no value is shown, light transmission is too small to measure

Description	Sample No.	Weave	Weight in sq. cms per 100 cms.)	Thickness in mms. at pressure of 10 gms. per sq. cm	Light* Trans-mission %	Perme-ability to air (in ccs. per sq. cm. for 1 cm. of water)	T.I.V. %	Remarks
Worsted suiting	33	Effect based on 2 × 2 Twill ...	3·42	0·74	...	5·7	34·8	...
" "	167	" " " ...	2·99	0·87	...	11·3	36·4	15/16 oz.
" "	168	" " " ..	2·92	0·95	...	13·5	34·8	15/16 oz.
" "	169	" " " ...	3·08	0·98	...	9·4	36·1	15/16 oz.
" "	171	" " " ...	3·85	1·10	...	5·6	34·3	18/19 oz.
" "	172	" " " ...	3·68	1·02	...	8·8	34·6	18/19 oz.
" "	173	Double plain	3·66	1·14	...	10·0	35·0	18/19 oz.
" "	170	2 × 2 Twill	2·90	1·02	...	9·1	35·0	15/16 oz.
Waterproofed coating ...	19	2 × 2 Twill effect	3·32	0·71	...	10·1	36·9	...
Woollen overcoating (light)	101	2 × 2 Twill H.B.	3·07	1·19	...	102	40·4	16 oz.
" " "	102	2 × 2 Twill H.B.	4·04	1·02	...	10·2	37·2	22/23 oz
Low woollen cloth ...	163	2 × 2 Twill H.B	5·00	1·73	0·3	35·0	42·7	11 oz., 36 in. wide
Fancy checkback	103	2 × 2 Twill face and plain back	3·74	1·09	...	29·6	41·3	17 oz.
Overcoating	9	Plain	4·07	1·98	...	197	43·9	...
"	23	2 × 1 Weft twill	7·35	2·21	...	7·3	42·8	...
"	30	3 × 1 Warp twill	5·36	1·29	...	16·0	41·7	...
"	32	2 × 1 Weft twill	7·45	2·54	...	13·5	43·5	...
"	39	3 × 1 Face and back	7·15	2·18	..	...	42·5	137 lb. per 64 yds.
"	40	3 × 1 Face and back	6·60	2·13	...	6·2	42·7	114 lb. per 64 yds.
"	99	2 × 2 Twill effect	5·52	1·75	...	20·0	40·3	28 oz.
"	174	2 × 2 Twill effect	4·46	2·00	...	14·8	40·1	...
"	175	6/2 2/2 Twill	5·64	2·32	...	10·8	41·0	...
"	176	3 × 1 Weft twill face and 3 × 1 weft twill back ...	5·04	2·52	...	24·2	44·8	...
"	177	6/1 face and 9/5 plain back ...	4·99	2·60	...	24·6	43·0	...

*Where no value is shown, light transmission is too small to measure.

Description	Sample No.	Weave	Weight (in sq. cms per 100 cms.)	Thickness in mms at pressure of 10 gms. per sq. cm.	Light* Trans-mission %	Perme-ability to air (in ccs. per sq. cm for 1 cm. of water)	T.I.V. %	Remarks
Yorkshire flannel ..	52	Plain	1·53	0·84	6·5	154	40·5	3·2 oz., 26 in. wide
,, ,, ...	53	,, ...	1·91	1·02	18·5	93·3	41·9	4.0 ,, 28 ,,
,, ,, ...	54	,, ...	2·22	0·92	3·1	43·5	40·5	5·0 ,, 30 ,,
Era flannel...	58	,, ...	1·36	0·43	6·5	91·2	37·1	3.0 ,, 27 ,,
,, ...	59	,, ...	1·43	0·51	5·9	61·7	39·0	3.8 ,, 30 ,,
Coarse flannel	60	,, ...	2·18	1·09	7·0	208	40·5	3·9 ,, 24 ,,
Army flannel	63	,, ...	2·24	1·14	3·4	124	41·1	4 9 ,, 27 ,,
Angola flannel	65	,, ...	2·14	0·81	2·2	73·2	39·7	5·2 ,, 28 ,,
Irish medium flannel ..	71	,, ...	2·14	1·40	6·2	334	41·9	4·7 ,, 26½ ,,
,, ,, ,, ...	72	. ...	2·28	1·52	5·3	178	41·5	5·5 ,, 29 ,,
All-wool flannel	74	,, ...	1·91	1·04	1·1	109	41·4	4·2 ,, 28 ,,
Flannel suiting	77	2 × 1 Twill	2·97	0·99	2·2	16·4	40·5	13·3 ,, 56 ,,
Angola shirting ...	80	Plain	2·19	0·71	1·7	41·5	40·2	5·0 ,, 28 ,,
Flannel dressing-gown fabric	76	2 × 2 Broken twill	2·43	1·88	0·6	100	45·5	8·5 ,, 45 ,,
Flannel suiting	79	2 × 1 Weft twill	2·92	1·22	...	35·7	40·4	13·9 ,, 56 ,,
,, , ...	78	2 × 2 Twill	3·04	1·12	0·3	23·6	40·2	14·4 ,, 56 ,,
Flannel	104	2 × 2 Twill	2·83	0·69	0·3	12·2	38·6	14 oz.
,, ...	105	2 × 1 Warp	2·78	0·81	0·6	18·7	37·8	14/15 oz.
Woollen blanket	131	Plain	4·52	5·16	1·4	65·0	59·3	...
,, ,, ...	132	,, ...	4·28	4·92	1·4	91·8	57·6	..
,, ,, ...	133	,, ...	5·12	5·06	1·4	71·5	58·2	...
,, ,, ...	134	,, ...	5·12	4·78	1·1	74·6	57·0	...
,, ,, ...	135	,, ...	4·88	4·65	0·6	105	56·9	...

*Where no value is shown, light transmission is too small to measure.

Description	Sample No.	Weave			Weight (in gms per 100 sq cms)	Thickness in mms at pressure of 10 gms per sq cm	Light* Transmission %	Permeability to air (in ccs per sq cm for 1 cm of water)	T.I.V. %	Remarks
Wool and cotton blanket	136	Plain			5·00	4·75	1·4	48·8	54·1	...
,, ,, ,,	137	,, ...			4·60	3·78	0·8	41·6	53·9	...
Wool blanket	13	,, ...			5·34	5·54	0·8	75·9	59·9	4 lbs.
Wool and cotton blanket	15	,, ...			5·35	3·56	0·6	26·6	55·0	4 lbs.
Wool blanket	25	,, ...			6·15	3·23	...	57·1	49·6	4 lb 11 oz
,, ...	123	Double plain			8·02	4·14	...	54·4	53·7	...
,, ...	130	4 Shaft satin			5·38	4·60	0·8	44·2	62·3	...
Wool rug	138	Double plain			7·56	5·03	...	52·6	56·0	...
Bar blanket (wool) ...	145	2 × 2 Twill			4·51	3·10	...	83·5	46·6	...
Blanket (wool)	146	2 × 2 Twill			4·44	3·61	2·2	86·9	47·9	.
		Wales	Courses	Holes per sq inch						
Knitted wool	1	26	34	884	1·75	0·74	16·8	357	38·4	...
,, cotton	2	25	36	900	1·53	0·53	12·1	250	36·0	...
,, artificial silk ...	3	28	32	896	1·71	0·48	25·5	1240	30·5	...
,, wool	4	24	24	576	2·74	1·09	7·8	197	40·6	...
,, ...	4A	18	20	360	3·48	1·14	9·5	84	41·2	...
,, ,, ...	5	19	23	437	2·69	1·24	10·4	139	37·0	...
,, ,, ...	5A	15	20	300	4·12	1·29	6·7	103	40·0	...
,, ,, ...	6A	22	26	572	2·67	1·02	7·3	71·5	36·5	...
,, artificial silk ...	7	28	36	1008	1·02	0·30	36·6	2000	30·1	...
,, ,, ,, ...	8	28	30	840	1·29	0·46	37·8	832	32·5	...
,, wool	11	20	26	520	2·90	1·17	8·4	122	37·6	...
,, ,, ...	12	22	26	572	2·74	1·12	12·6	175	39·0	...
,, ,, ...	200	28	38	1064	1·71	0·25	8·0	71·5	38·8	...
,, ,, ...	201	27	36	972	1·93	0·76	6·7	98·1	39·1	...
. . ...	202	22	30	660	2·61	0·89	5·3	69·0	41·1	...

*Where no value is shown, light transmission is too small to measure.

Description	Sample No.	Weave	Weight (in gms per 100 sq. cms)	Thickness in mms. at pressure of 10 gms. per sq. cm.	Light* Transmission %	Permeability to air (in ccs per sq. cm. for 1 cm. of water)	T.I.V. %	Remarks
Aertex cotton	148	342 holes sq. inch	1·42	0·72	20·7	385	34·8	...
,, ,, ...	149	195 ,, ,, ...	1·24	0·74	22·4	766	33·4	...
,, ,, ...	150	196 ,, ,, ...	1·55	0·94	19·6	555	34·8	...
,, ,, ...	151	225 ,, ,, ...	1·79	0·86	16·8	385	35·5	...
,, ,, (lisle) ...	152	506 ,, ,, ...	1·31	0·86	16·8	766	35·4	...
,, ,, ,, ...	153	700 ,, ,, ...	1·19	0·72	19·3	588	35·5	...
,, cotton and art. silk.	154	736 ,, ,, ...	1·23	0·53	16·5	303	34·8	...
,, ,, wool ...	155	380 ,, ,, ...	1·42	0·97	19·3	434	37·3	...
,, ,, ,, ...	156	121 ,, ,, ...	2·00	1·09	10·1	277	41·5	...
Celanese fabric	178	8 End satin	1·26	0·15	1·4	13·5	37·8	...
,, ,, ...	179	Plain	1·09	0·21	8·7	92·5	36·0	...
,, ,, ...	180	,, ...	0·50	0·18	26·3	831	27·0	...
,, ,, ...	181	,, ...	1·40	0·25	...	125	34·7	...
,, ,, ...	182	,, ...	1·33	0·21	1·1	42·4	34·3	...
,, ,, ...	183	,, ...	0·62	0·08	12·1	46·8	33·2	...
,, ,, ...	184	2 × 1 Warp twill	0·85	0·10	2·2	9·8	33·2	...
,, ,, ...	185	Plain	0·88	0·13	2·5	10·7	36·5	...
,, ,, ...	186	,, ...	0·73	0·10	7·8	19·6	34·9	...
,, ,, ...	187	,, ...	0·57	0·10	46·0	1000	27·5	...
,, ,, ...	188	2 × 1 Warp twill	0·76	0·10	6·0	18·9	33·6	...
,, ,, ...	189	2 × 2 Twill	0·90	0·12	8·1	8·6	33·7	...
,, ,, ...	190	Plain	0·55	0·18	10·8	182	32·2	...
,, ,, ...	191	,, ...	0·78	0·18	7·9	65·0	32·9	...
,, ,, ...	192	4 Shaft satin	0·83	0·10	8·7	29·4	39·0	...
,, ,, ...	193	Plain	0·97	0·25	2·7	161	31·6	...
,, ,, ...	194	2 × 1 Twill	1·05	0·15	9·4	16·1	35·0	...
,, ,, ...	195	Plain	0·73	0·15	6·6	82·0	32·8	...

*Where no value is shown, light transmission is too small to measure.

Description	Sample No.	Weave	Weight (in gms. per 100 sq. cms.)	Thickness in mms. at pressure of 10 gms. per sq. cm.	Light* Trans-mission %	Perme-ability to air (in ccs. per sq. cm for 1 cm. of water)	T.I.V. %	Remarks
Cotton duck	28	Plain	4·59	0·76	1·4	...	36·4	...
„ drill	34	3 × 1 Twill	3·26	0·58	1·7	...	37·8	...
Unbleached calico ..	36	Plain	2·09	0·46	2·8	14·2	38·2	...
Cotton duck	37	Plain	3·14	0·41	1·1	...	38·4	...
Buttermuslin	144	„	0·45	0·18	29·2	...	29·5	...
Calico	143	„	0·66	0·10	7·3	...	37·5	...
Linen	35	Plain	1·28	0·16	4·2	17·6	36·5	...
Linen duck ...	38	„	4·39	0·56	0·8	2·8	38·0	...
Sheer linen...	157	„	0·59	0·10	20·7	715	33·8	...
„	158	„	0·57	0·08	18·5	555	33·1	...
„	159	„	0·55	0·08	19·7	415	33·6	...
Cambric	160	„	0·81	0·10	14·8	370	35·1	...
„	161	„	0·81	0·10	15·7	208	34·9	...
„	162	„	0·78	0·08	17·1	139	34·8	...
Twilled silk for foulards	164	2 × 1 Twill	0·73	0·10	3·6	12·3	37·8	2 oz., 36 in. wide
Pure silk taffeta	165	Plain	0·74	0·13	7·6	45·5	38·0	2 „ 32 „
Pure silk crêpe-de-chine ...	166	„	0·43	0·10	17·6	143	30·0	1¾ „ 38 „
Felt	21	... ...	6·74	2·39	...	10·0	45·8	...

*Where no value is shown, light transmission is too small to measure.

From these tables, thermal insulating values were plotted against thickness and weight per unit area (Figs. 6 and 7 respectively).

The thicknesses used are those at 10 grms. per square cm. Measurements were taken at pressures of 0·1 and 1 grm. per square cm. and plotted against the T.I.V., but gave more scattered points. This would indicate that it is the more solid part of a fabric which is important in therma insulation, while the projecting fibres are not of great importance.

In Fig. 6 the points lie very approximately on a straight line which does not pass through the origin. This linear relationship holds over a very wide range of thicknesses, covering every type of fabric and raw material. It may be said, therefore, that *the chief factor which determines the thermal insulating value of a fabric is its thickness*, the thickness excluding the projecting fibres. There are certainly other factors, but thickness appears to be the predominant one.

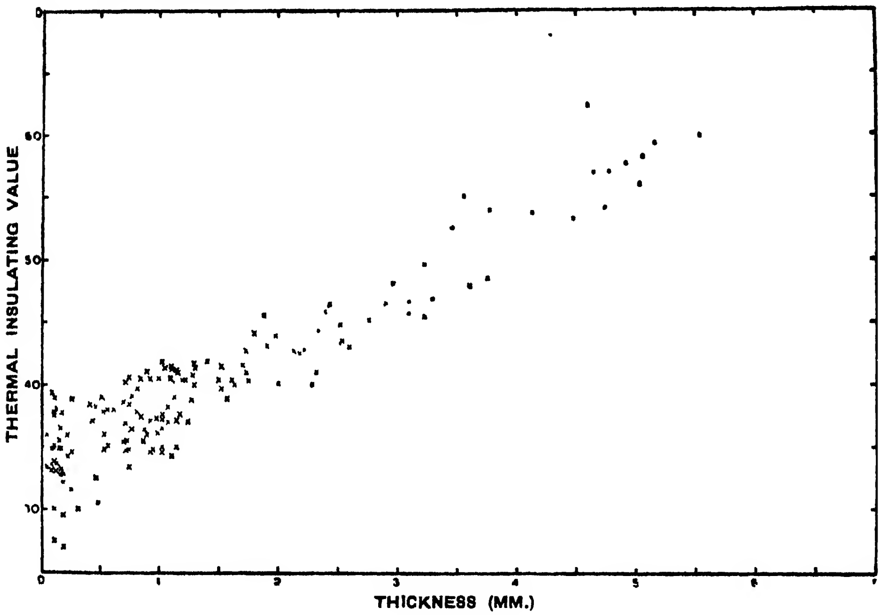


FIG. 6

It should be noted that the average straight line drawn through the points does not pass through the origin, but that for small thicknesses there is a thermal insulating value of about 30 per cent. This is probably due to the breaking up of the convection currents, which are responsible to a large extent for the loss of heat from a body in air.

Confirmation of this is found when deviations from the average straight line through the points are considered. All the fabrics, especially those under 1 mm. thick with a large permeability to air, have a low insulating value. In these cases warm air can pass directly through the interstices of the fabric, thus causing a greater heat loss than would be expected from the thickness measurement. Similarly those fabrics with a high light-transmission give a low insulating value, since they allow direct passage of heat radiation and convection.

In order that these ideas might be tried out by extreme tests, several unusual coverings were investigated. A thick very open net gave a value

much lower than any other fabric of the same thickness. On the other hand, tracing linen and paper, which are impervious to air, gave high results in accordance with those of comparable fabrics.

A further very interesting experiment was made on thin sheet brass. It gave a thermal insulating value of about 54% when blackened, and about 72% when polished. Here the conductivity of the metal is so high that the resistance to passage of heat through it is negligible. Under these conditions, on the assumption that the heat passing across the space is proportional to the temperature-difference, the conducting plane should cut down heat loss to 50% if its surfaces are perfectly absorbing and radiating. Actually the blackened surfaces do not fulfil the condition completely, so that the thermal insulating value is rather over 50 per cent. When the surfaces are bright, this effect is increased, so that thermal insulating value is greatly increased. This is a similar effect to that shown in the earlier experiments on the loss of heat from the uncovered heater to polished and black surfaces.

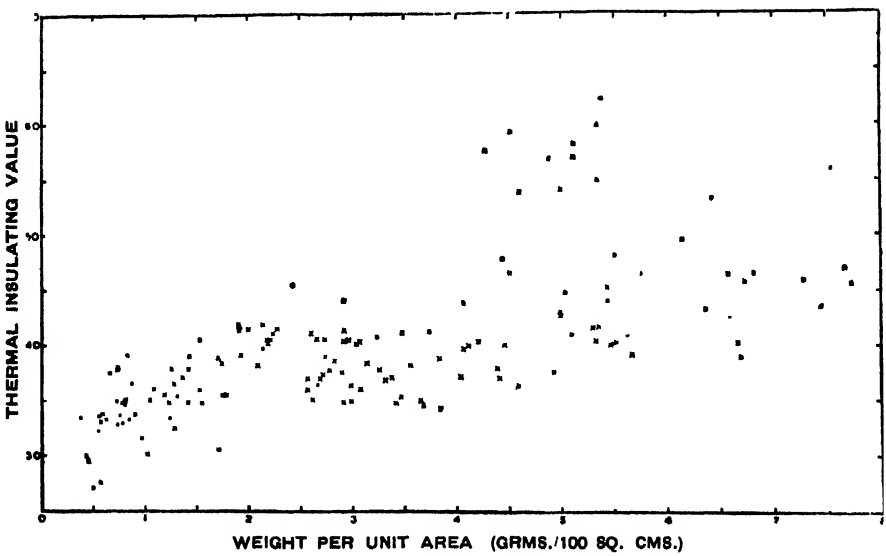


Fig. 7

It may now be asked why a good conductor, such as brass, is under these conditions a far better insulator than fabrics, whose conductivity as ordinarily determined is much lower. This cannot be altogether explained by the imperviousness to air of the metals, as some of the fabrics did not allow any passage of air at all. It is suggested that the effect is due to the larger surface of the fabric in which more heat can be received and lost by convection. Confirmation of this is given by the fact that thin sleeves fitted directly on the heater caused it to lose more heat than it lost when bare. It was also found that a smooth, shiny-surfaced, fabric had a high insulating value. Gregory[38] has shown recently that fabrics have an emissivity ten times as great as polished copper.

Fig. 7 shows thermal insulating value plotted against weight per unit area, and shows there is no direct relationship except perhaps a slight increase

in thermal insulating value with weight. Again, however, the positions of certain fabrics and groups of fabrics, related to their other physical properties, give definite information.

From the thickness at 10 gm./cm.^{2} and the weight per unit area, the density has been calculated. No definite relationship appears to exist between thermal insulating value and density for the same weight or thickness, but there is a marked tendency for the less dense fabrics to show a higher thermal insulating value than others.

Passing from these generalisations to a more detailed analysis of the results, a large mass of facts calls for comment.

Most of the work on heat flow through fabrics has been done with the object of deciding the relative value of different fibres for thermal insulation. Many comparisons have been made, but it is very easy to misinterpret experimental results on this point. The great difficulty is in the very different types of fabrics produced by different fibres.

For instance, the question is often raised as to whether silk is "warmer" than wool. This is very difficult to answer, as very few silk fabrics are more than 0·3 mm. thick, while very few wool fabrics are less than 0·5 mm. thick. Even if two fabrics, one of silk and one of wool, were found to be of the same thickness, each would be an extreme of its class, and therefore not truly representative.

A comparison of silk and linen brings out another difficulty in comparing different fibres. Tests were made on a number of silk and linen fabrics whose thicknesses were all 0·1 mm. The linens (sheer linens and cambrics) had thermal insulating values between 33% and 35%, while among the silks a crêpe-de-chine has a value of 30%, and a twilled silk for foulards 37·8%. The structure is, therefore, of the utmost importance. It may be mentioned that the crêpe-de-chine had a permeability about twelve times that of the other silk fabric.

It is therefore, unjust to compare the thermal insulation of textile materials by comparing certain fabrics made of each. From this work, it is believed that it would be possible to make a fabric of a given insulating value from any of the textile materials. It would only be necessary to make it sufficiently thick and of close structure. The reasons why this is not done commercially are apparently considerations of cost and weight. From a general review of fabrics made, it would appear that wool is the main material for making thick fabrics, and has therefore earned the name for being warmer than other materials.

From the results on blankets, it is found that those of high quality wool have a higher insulating value than those of the lower grades.

Similar remarks would apply to mixed fabrics, such as union blankets and flannels. These have, in general, a lower insulating value than those of pure wool, but it is apparently possible to reverse the position.

Another demonstration of the effect of structure is in the case of all-wool suitings. In general, woollen cloths have higher insulating value than worsted, due no doubt to the different structure of the yarn, and the greater extent of milling in most woollens.

To test the effect of milling on thermal insulation and air permeability, a cream woollen cloth was milled for several periods of half an hour each

At the end of each period a sample was taken out and tested. The thermal insulating value increased in the following manner—

Original cloth	38·0
After ½ hour milling	40·9
„ 1 „	42·2
„ 1½ hours milling	46·0
„ 2 „	46·8
„ 2½ „	47·7
„ 3 „	50·0

Other experiments gave similar results. It has been found in every case that milling diminishes the permeability to air, and it would therefore be expected to increase the thermal insulating value.

In the case of some artificial silks, it was found that those with a very shiny surface tended to have high insulating values. This would be expected since these would reflect more of the radiant heat than those with a dull surface.

No evidence has been found of colour affecting thermal insulating value. The difficulty of detecting this effect is the change of a fabric when it is dyed.

Attempts have been made to obtain a formula for the thermal insulation of a fabric in terms of its other physical properties, but these have met with no success. The only way to determine the insulating value of a fabric is experimental. A brief discussion of heat flow through fabrics is given elsewhere.[43]

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16—THE DETERMINATION AND VARIATION OF TWIST IN RING-SPUN COTTON YARNS

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SUMMARY

In the present paper it is pointed out that the determination of twist in single cotton yarn is a matter of considerable difficulty, especially when the yarn has been spun from a short staple cotton. Large numbers of tests have been made on single yarns by the usual method of removing the twist in a Standard Twist Tester.

A new method of twist testing is described which consists of passing two single yarns between the front rollers of the ring frame and spinning in the usual way, so that the total doubling twist is substantially the same as in an equal length of single spun yarn. Twist tests on twofold yarns can be made with very great accuracy, using 10-inch lengths, and this method has therefore been employed for the purpose of investigating the variation of twist throughout the bobbin, and also for ascertaining if the variation of twist is affected by the variations in the winding-on tension or by variations in counts.

In an Appendix some results are given of certain observations on the relation between the spindle speeds as observed by means of a tachometer and as calculated from the front roller speed, also measured by a speed indicator.

The experiments have been carried out on Punjab-American 285F, spun into single yarns of 20's, 30's, and 40's counts, and also made into twofold grandrelle yarns of 2/40's, 2/60's, and 2/80's counts. The results of a large number of other tests on the standard Indian cottons have also been analysed in arriving at the conclusions, which are as follows—

(1) When single yarns are tested for twist by the ordinary method it is necessary to make at least 100 observations on 1-inch lengths in order that the odds may be 5 to 1 that the mean value is correct within 2% on either side of the mean.

(2) When a grandrelle yarn is made above a single yarn on the same bobbin by doubling together two single yarns, under the same spinning conditions as those employed in the spinning of the single yarn, only ten determinations of twist in 10-inch lengths need be made on the grandrelle yarn in order that the odds may be 10 to 1 that the mean value is correct within 2% on either side of the mean.

(3) The practice at the Technological Laboratory of making ten tests on the grandrelle yarn spun at the top of each of ten bobbins enables the checking of the correctness of the twist wheel to be carried out to a very high degree of certainty.

(4) While the insertion of twist leads to a contraction of the yarn during spinning, this may be partly offset by an extension due to the effect of the winding-on tension.

(5) In calculating the twist per inch in the yarn from the "constant dividend" for twist, the allowance which is made for the thickness of the spindle bands and band slippage should be 8·5 per cent.

(6) Any effect on the twist per inch of a difference in the winding-on tension at the apex and base of the chase appears to be completely masked by irregularities due to other causes.

(7) Very little variation should exist in the total twist of successive long lengths of yarn wound on the bobbin; where such differences do exist they indicate the existence of variation either in the winding-on tension, or in the spindle-band tension during spinning.

(8) The variation of twist in successive 6-inch lengths of yarn is chiefly conditioned by the variation of count along the yarn.

I—INTRODUCTION

A cotton yarn without twist is a physical impossibility; further, it is the degree of twist that largely determines the character and strength of a cotton yarn. The testing of single yarn for twist is therefore a matter of some importance, as it is frequently desired to know whether the twist in a given batch of yarn conforms to some standard known to be suitable for a given type of fabric. But the accurate determination of twist in single cotton yarn is not at all an easy matter, especially when the yarn has been spun from a short staple cotton. The reason for this lies in the method almost universally adopted for the test, viz., the removal of the twist by turning the yarn on its axis, the number of turns required for the removal of the twist being automatically recorded by some counting device. If the test-length of the yarn is as much as one inch, then, when most of the twist has been removed, there is nothing to hold the fibres together and they consequently tend to escape from their original alinement; the trouble is accentuated by the fact that as the twist is removed the yarn extends, and as the distance between the jaws is kept fixed, forces at right angles to the yarn axis are called into play tending to separate the fibres from one another, with the consequence that it is a matter of some difficulty to decide on the exact moment when the twist has been removed from the single yarn. The trouble may be overcome to some extent by reducing the length of the specimen to half an inch, but even so a considerable amount of care must be exercised in the test in order to obtain accurate results. It is clear that with such a small length of specimen great care must also be exercised in the sampling of the yarn, and normally it is obviously desirable that a large number of tests should be made.

The subject of twist testing has assumed importance at the Technological Laboratory because of a desire to check the twist inserted in yarn during a spinning test. In the earlier tests it was found that quite divergent results were obtained; in some cases indeed it was reported that the yarn had a twist considerably in excess of the nominal; such results could obviously only be explained either by a mistake having been made in the gearing wheels used in spinning, or by a mistake having been made in the twist testing. For this reason a thorough investigation has been made into the method of twist testing, with results to be described in the present paper.

Large numbers of tests have been made on single yarns by the usual method; and a new method has been investigated, consisting of passing two single yarns between the front rollers of the ring frame and spinning in the usual way. In the second method the total doubling twist must be substantially the same as in an equal length of single spun yarn, for the front-roller speed and the spindle speed remain the same. As twist tests on twofold yarn can be made with very great accuracy, using 10 in. lengths, this method was employed for investigating the variation of twist throughout a bobbin, and also for ascertaining if the variations of twist were affected by the variations in the winding-on tension or by variations in counts. As a matter of interest some observations were also made on the relation between the spindle speeds as observed by means of a tachometer and as calculated from the front roller speed; the results of these tests are given in the Appendix.

II—EXPERIMENTAL MATERIALS AND METHODS

Cotton—All the yarns used in these experiments have been spun from Punjab-American 285F (season 1926–27).

Counts—Single yarns of 20's, 30's, and 40's were spun having nominal twists of 16·64, 21·58, and 26·62 turns per inch respectively.

Twofold grandrelle yarns were spun of 2/40's, 2/60's, and 2/80's also having nominal twist of 16·64, 21·58, and 26·62 turns per inch of doubling twist respectively.

Testing machine—The twist testing machine used in these tests was a Baer Twist Counter No. 8.

Procedure for testing single yarns—In view of the conditions under which the twist is inserted in yarn, it is evidently desirable to test the total amount of twist in a few long lengths of yarn rather than the amount in a large number of places widely separated. Tests were therefore made on 2,000 successive 1-in. lengths of the 20's yarn, and 600 successive 1-in. lengths from each of the 30's and 40's counts. The method of ensuring no loss of twist in the testing of successive 1-in. lengths was as follows—After each specimen had been tested for twist, the end of the yarn in the sliding jaw was nipped by forceps and transferred to the revolving jaw, which was then closed; uniform tension was then applied to the specimen by suspending from the yarn a small spring clip weighing 10·24 grams, and while the yarn was thus under tension the sliding jaw was closed. The twist was then removed from the specimen in the usual manner, and the amount of twist as given by the reading of the counting device was duly recorded.

The bobbin containing the yarn for testing is carried in a horizontal position on a wooden stand so as to enable the yarn to be drawn off from the nose of the bobbin. It is sometimes stated that in twist-testing the yarn should be drawn off from the side of the bobbin, which is thereby caused to revolve as the yarn is withdrawn; such a method is incorrect, however, for two reasons. First, the calculation of nominal twist is based on the number of spindle revolutions and on the delivery of yarn from the front roller; no allowance is made for the lag of the traveller necessary for winding. Now the number of revolutions which the traveller loses as compared with the bobbin represents exactly the number of coils wound on the bobbin. Hence, as by removing the yarn from the nose of the bobbin one turn of twist is given to the yarn for every coil, these additional twists received by the yarn exactly compensate for the twist lost in winding on to the bobbin, on the number of revolutions of which the calculation of twist is based; hence in comparing the actual twist in the yarn with the calculated, it is essential to remove the yarn from the nose of the bobbin. Secondly, whether the yarn is subsequently used for warp or weft the yarn is likewise removed from the nose of the bobbin, so that this method of testing does give the amount of twist actually in the yarn in use.

Procedure for spinning and testing twofold yarns—Two single yarns, one grey and the other coloured, were subjected to a doubling process simultaneously with the spinning of the single yarns. Three bobbins, one each of a grandelle yarn of equivalents count 20's, 30's, and 40's, were obtained in this way. For the 20's equivalent counts a bobbin of 40's singles grey and another of 40's singles yellow were placed on a small stand specially constructed to hold the bobbins; the stand was interposed between the

creel and the back line of rollers of the ring frame; the two ends from each pair of bobbins were taken off vertically and led over a guide rod so that the yarns might come off easily from the nose of the bobbin, and then over the back and middle bottom rollers (the top rollers being removed), and finally run through the pair of front rollers and through the thread guide and traveller, and so on to the bobbin on which they were to be wound after being doubled together. The doubling of the 40's singles thus gave a yellow-grey grandrelle yarn having a count equivalent to approximately 20's singles In similar fashion blue-grey and red-grey grandrelle yarns were produced of 2/60's and 2/80's, approximately equivalent to 30's and 40's singles respectively, the doubling being carried out simultaneously with the spinning of the 30's and 40's singles respectively.

Each of the three grandrelle yarns was completely tested for twist; the tests were made on successive 10 in. lengths, the procedure in twist testing being much the same as for the single yarn, except that the extension of the yarn on twist removal was also measured. The use of double yarns made it possible to determine the twist with a high degree of accuracy, firstly, because specimens 10 in. long could be used, and secondly, because it was easy to discern when all the twist had been removed from the yarns.

III—DISCUSSION OF THE RESULTS

Number of tests required in routine twist-testing— In order to analyse the results obtained by the two methods of twist-testing, the values of twist per inch in the single yarns have been grouped together as follows—In the first place, the whole 2,000 values for 20's counts have been grouped so as to give a frequency-table, Table I, and a frequency-polygon, Fig. 1. Only 600 values were available for 30's and 40's counts, and their frequency-distributions are shown in Table II, and in Fig. 1. The results have also been grouped in another way, viz., in the form of means of successive sets of 10, 20, and 50 respectively; in the case of the 20's counts similar groupings have also been carried out for successive sets of 100, 150, and 200. The frequency-distributions of the 20's, 30's, and 40's counts are shown in Tables I and II respectively, and graphically in Figs. 2, 3, and 4.

Table I

Frequency-distribution of Twist in 20's Singles

Twist (turns per inch)	Frequency for sets of 10	Twist (turns per inch)	Frequency for sets of 20	Twist (turns per inch)	Frequency for sets of 50	Twist (turns per inch)	Frequency for sets of 100	Twist (turns per inch)	Frequency for sets of 150	Twist (turns per inch)	Frequency for sets of 200
15·0	0	16·0	1	17·0	2	17·0	1	...	...	...	...
15·5	3	17·0	10	17·3	6	17·3	2	17·3	2	17·3	2
16·0	7	17·3	17	17·6	12	17·6	8	17·6	5	17·6	5
16·5	21	17·6	22	17·9	16	17·9	8	17·9	6	17·9	3
17·0	21	17·9	26	18·2	4	18·1	1	...	...	...	...
17·5	49	18·2	18	...	...	...	...	...	...	...	...
18·0	41	18·5	4	...	...	...	...	...	...	...	...
18·5	36	18·9	1	...	...	...	...	...	...	...	...
19·0	14	19·0	1	...	...	...	...	...	...	...	...
19·5	6	...	...	...	...	...	...	...	...	...	...
20·0	2	...	...	...	...	...	...	...	...	...	...
Totals	200	...	100	...	40	...	20	...	13	...	10

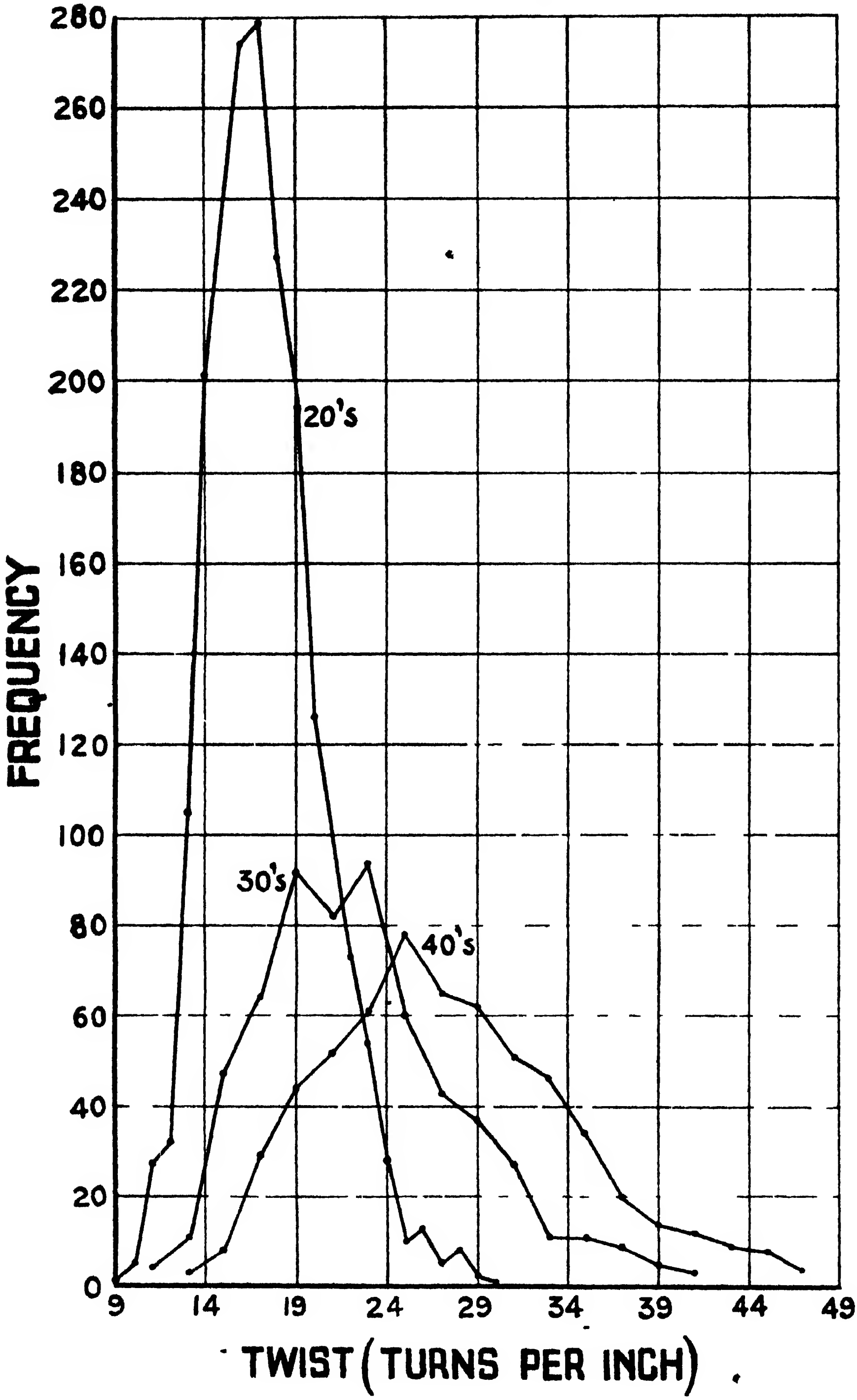

FIG. 1

Frequency-distribution of individual twist-values for 20's, 30's, and 40's singles yarns.

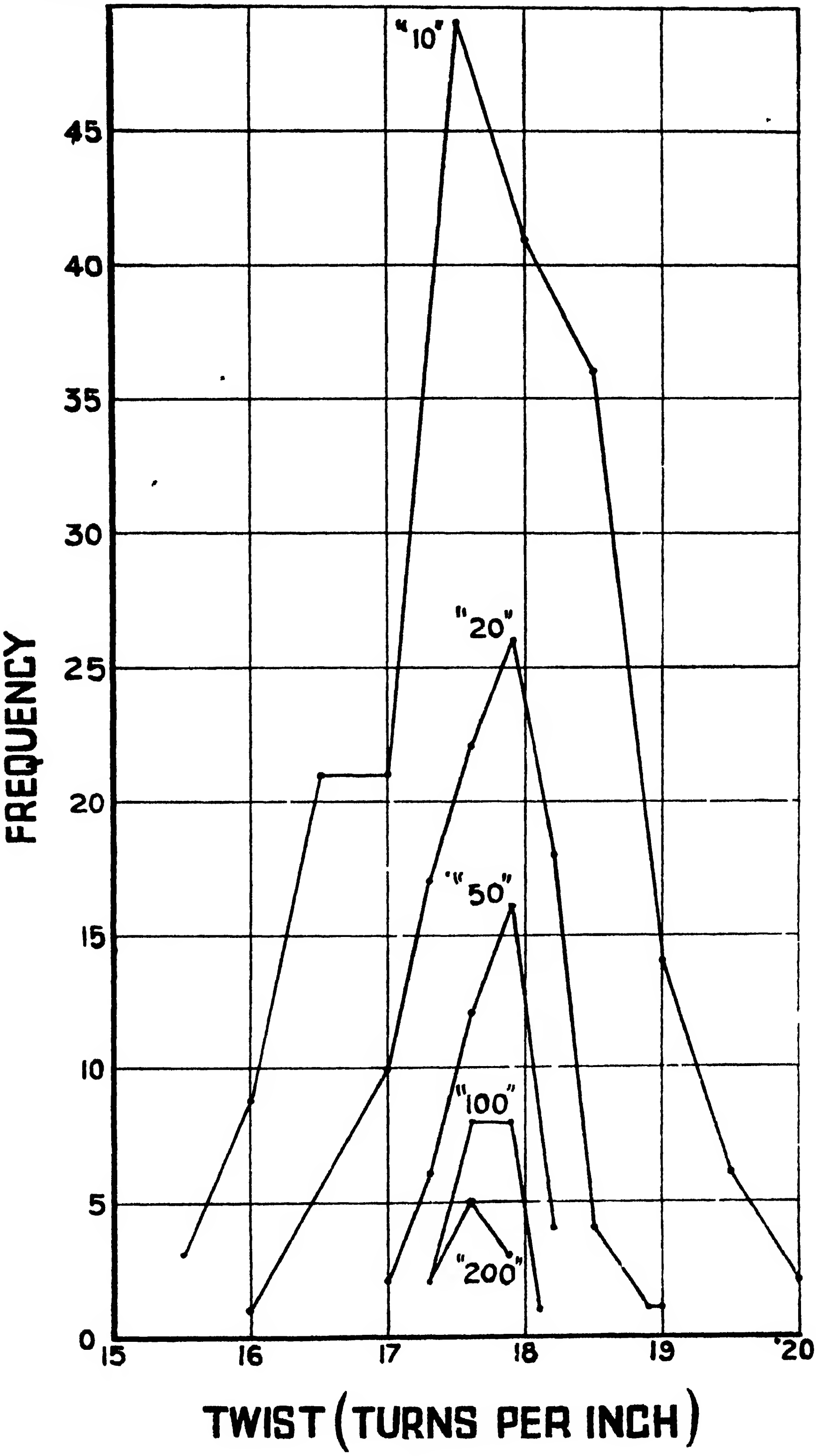

FIG. 2

Frequency-distribution of mean twist-values for sets of 10, 20, etc., for 20's singles.

A similar method has been followed in the grouping of the results for the twofold yarns. In this case the individual test-values available were 3,200 for the 2/40's, 4,600 for the 2/60's, and 4,300 for the 2/80's. The

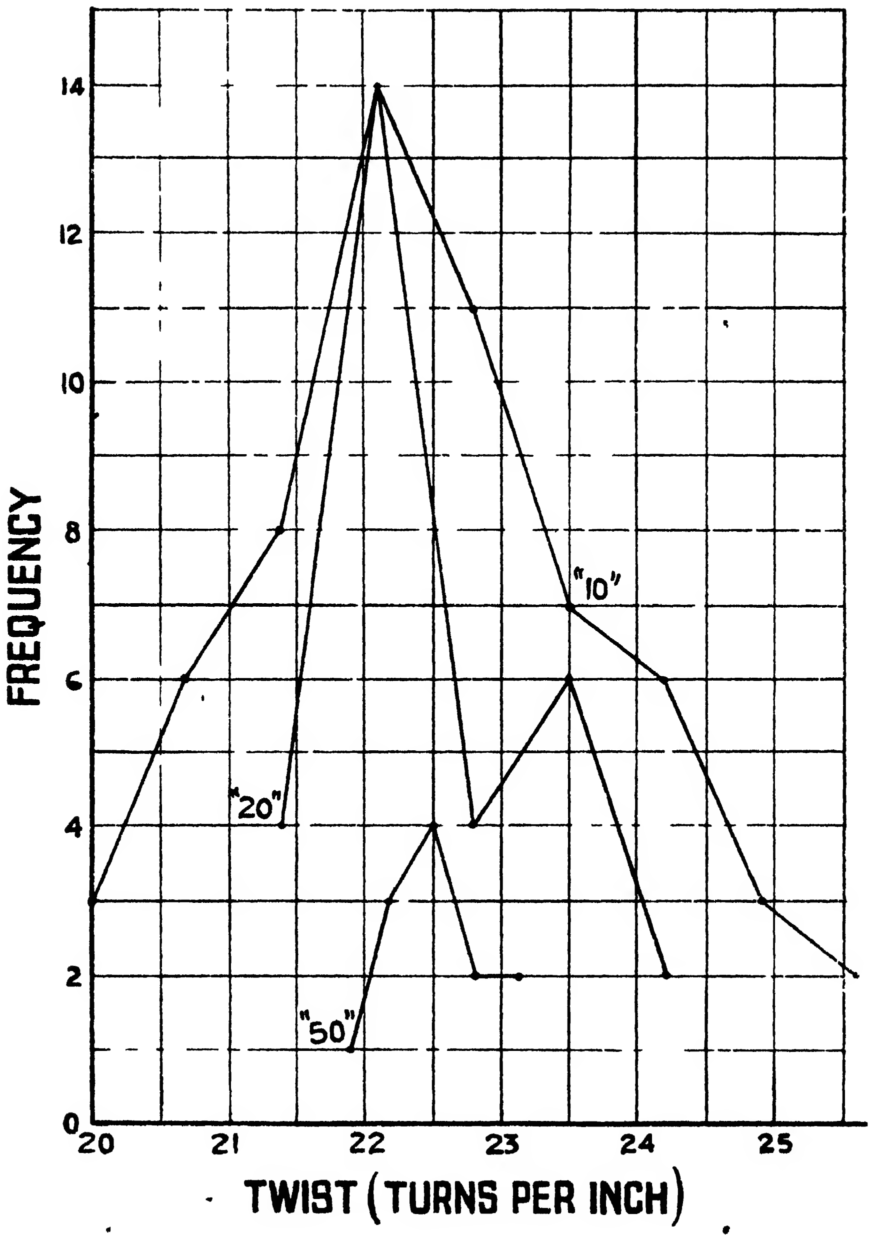

Fig. 3

Frequency-distribution of mean twist-values for sets of 10, 20, etc., for 30's singles.

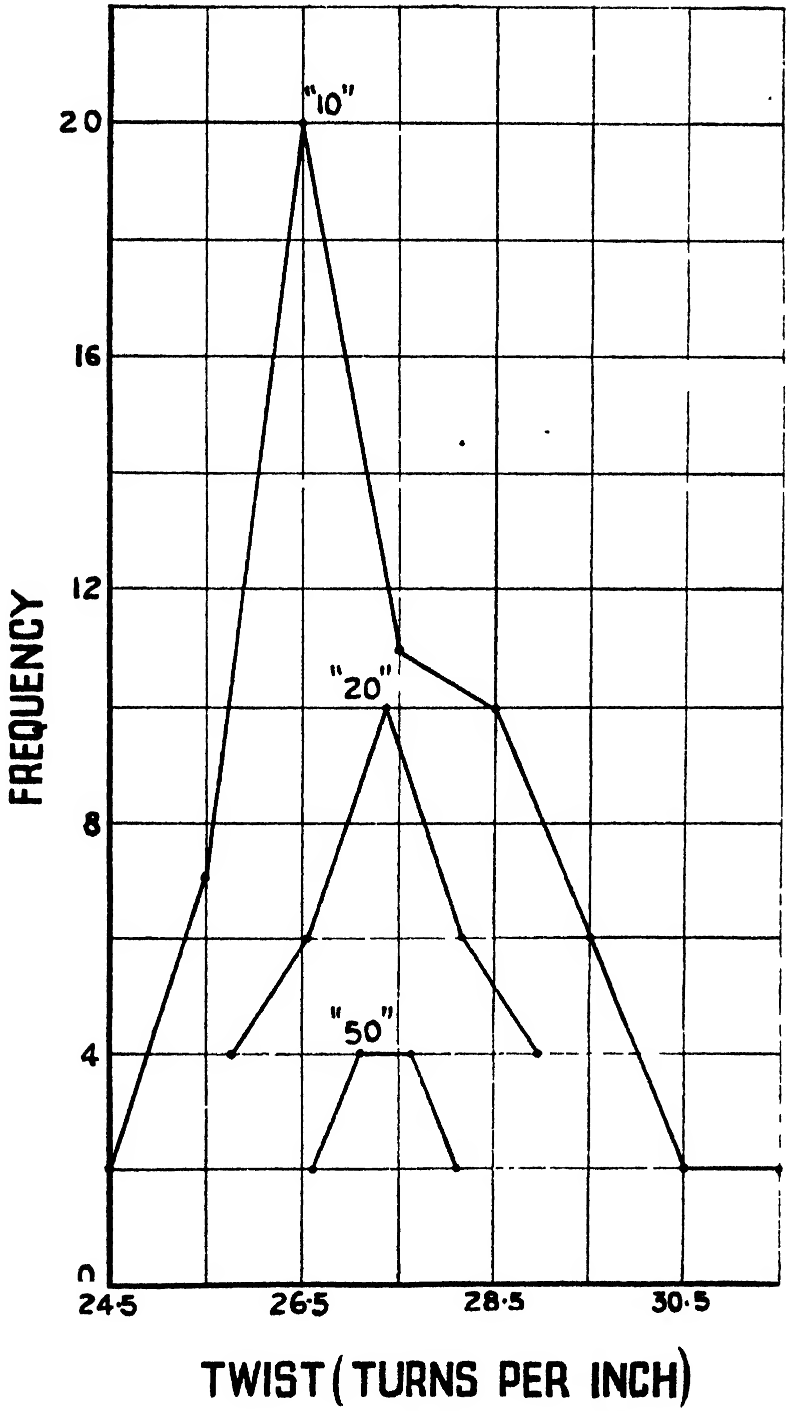

FIG. 4

Frequency-distribution of mean twist-values for sets of 10, 20, etc., for 40's singles.

Table II
Frequency-distribution of Twist for 30's and 40's Singles

30's Counts						40's Counts					
Twist (turns per inch)	Frequency for sets of 10	Twist (turns per inch)	Frequency for sets of 20	Twist (turns per inch)	Frequency for sets of 50	Twist (turns per inch)	Frequency for sets of 10	Twist (turns per inch)	Frequency for sets of 20	Twist (turns per inch)	Frequency for sets of 50
20·0	3	21·4	4	21·9	1	24·5	2	25·75	4	26·6	2
20·7	6	22·1	14	22·2	3	25·5	7	26·55	6	27·1	4
21·4	8	22·8	4	22·5	4	26·5	20	27·35	10	27·6	4
22·1	14	23·5	6	22·8	2	27·5	11	28·15	6	28·1	2
22·8	11	24·2	2	23·1	2	28·5	10	28·95	4	...	...
23·5	7	...	...	...	...	29·5	6	...	...	...	...
24·2	6	...	...	...	...	30·5	2	...	...	...	...
24·9	3	...	...	...	...	31·5	2	...	...	...	...
25·6	2	...	...	...	...	...	...	...	...	...	...
Totals	60	...	30	...	12	...	60	...	30	...	12

Table III
Frequency-distribution of Doubling Twist in 2/40's, 2/60's, and 2/80's

2/40's				2/60's				2/80's			
Twist (turns per inch)	Frequency for Sets of			Twist (turns per inch)	Frequency for Sets of			Twist (turns per inch)	Frequency for Sets of		
	10	20	50		10	20	50		10	20	30
15·7	1	...	...	20·2	1	...	...	24·8	1	..	...
15·8	5	...	...	20·3	0	...	...	24·9	0	...	...
15·9	4	...	...	20·4	1	1	...	25·0	0	...	...
16·0	4	3	...	20·5	4	0	...	25·1	0	..	...
16·1	22	5	1	20·6	8	2	.	25·2	1	...	...
16·2	23	17	7	20·7	12	4	1	25·3	1	...	...
16·3	66	25	10	20·8	28	4	0	25·4	2	...	...
16·4	45	31	16	20·9	23	13	0	25·5	4	...	...
16·5	46	27	15	21·0	46	23	11	25·6	9	1	...
16·6	43	24	6	21·1	55	29	20	25·7	2	3	...
16·7	25	16	7	21·2	63	49	21	25·8	9	4	...
16·8	16	9	2	21·3	53	41	18	25·9	19	7	1
16·9	13	3	...	21·4	72	30	14	26·0	33	10	6
17·0	5	...	...	21·5	43	13	6	26·1	45	21	3
17·1	1	...	..	21·6	20	14	1	26·2	53	33	18
17·2	1	..	..	21·7	21	6	...	26·3	70	44	27
...	...	..		21·8	7	1	...	26·4	56	37	20
...	...	...	.	21·9	1	...	...	26·5	32	26	7
...	...	...	...	22·0	0	...	...	26·6	49	15	3
	...	...	..	22·1	1	...	...	26·7	22	7	1
..	...	...	..	22·2	0	...	...	26·8	6	3	...
...	...	...	...	22·3	1	...	...	26·9	8	1	...
...	...	...	...	...	...	...	...	27·0	3	1	...
...	...	...	...	...	...	...	...	27·1	4	2	...
...	...	...	...	...	...	...	...	27·2	1	...	...
...	...	...	...	...	...	...	...	27·3	0	...	...
...	...	...	...	...	...	...	...	27·4	1	...	...
...	...	...	...	...	...	...	...	27·5	0	...	...
...	...	...	...	...	...	...	...	27·6	2	...	...
...	...	...	...	...	...	...	...	27·7	1	...	...
Totals	320	160	64	...	460	230	92	...	430	215	86

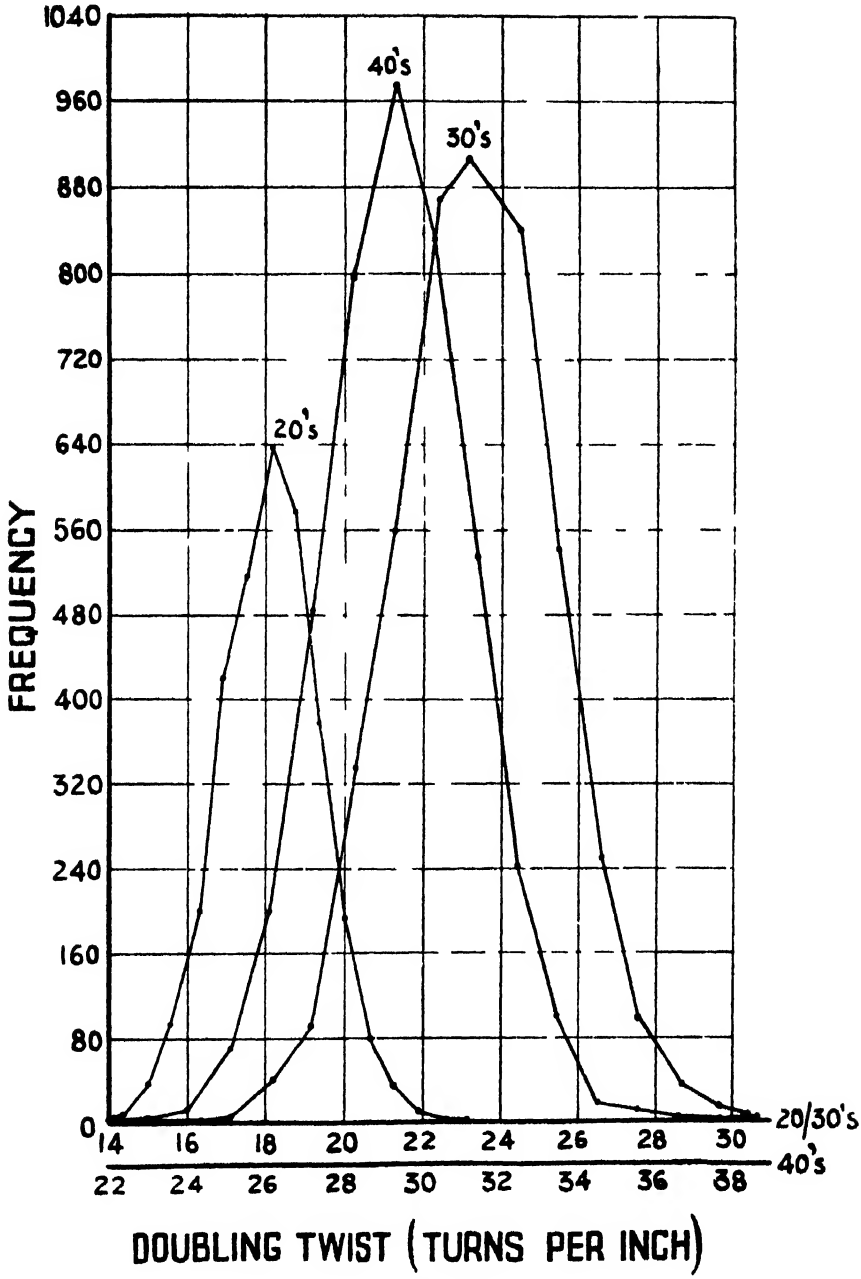

Fig. 5

Frequency-distribution of individual twist-values for 2/40's, 2/60's, and 2/80's.

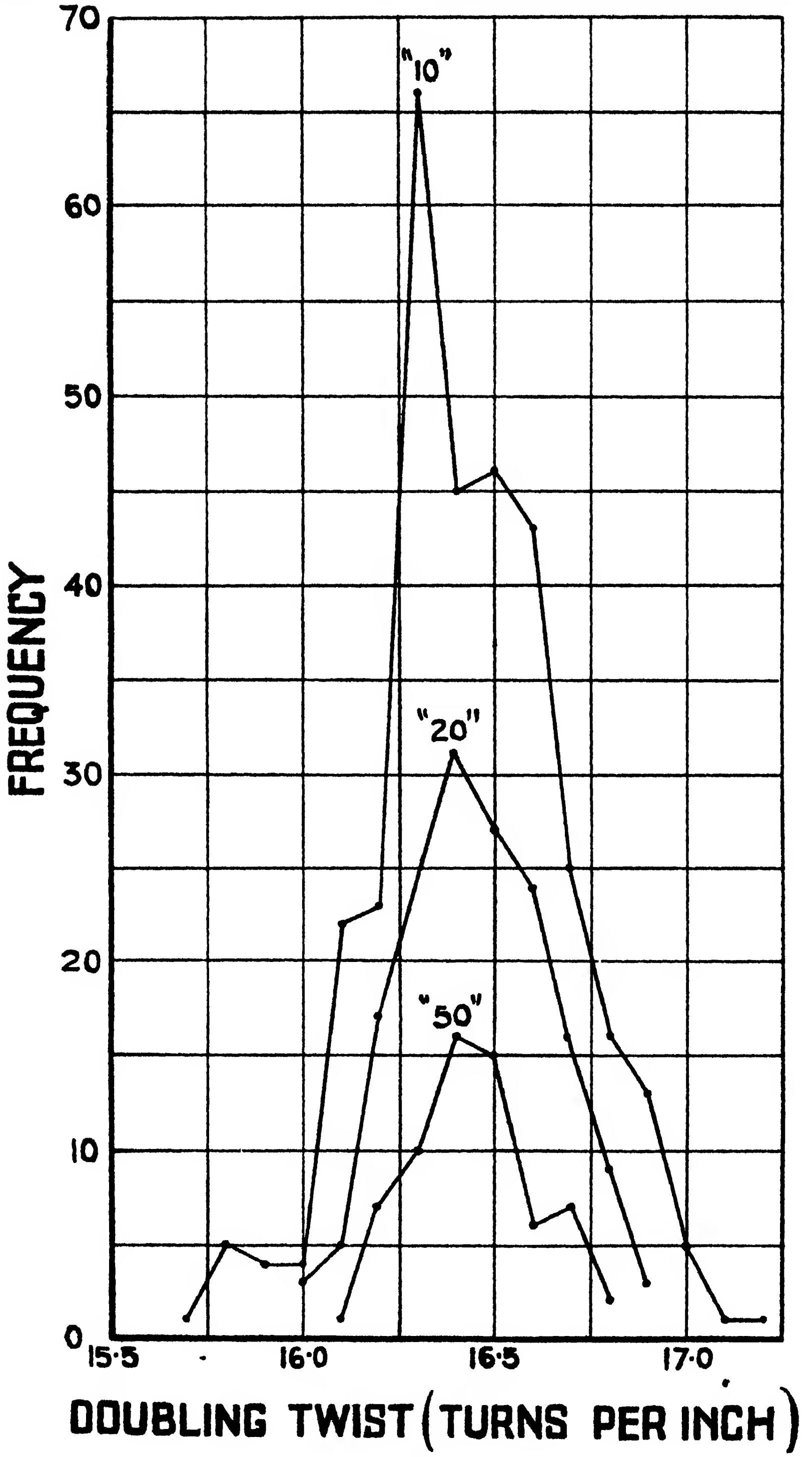

FIG. 6

Frequency-distribution of mean twist-values for sets of 10, 20, etc., for 2/40's.

frequency-distributions of the individual values for the 2/40's, 2/60's, and 2/80's are shown in Table III and Fig. 5, and the frequency-distributions of the means of successive sets of 10, 20, and 50 values are also given in Table III, and in Figs. 6, 7, and 8.

It will be observed that the means in each case are of successive sets of test-values, and therefore each mean represents the average amount of twist in one continuous length of yarn in which all the twist has been actually determined; the advantage of this method of grouping lies in the fact that with a given delivery from the front rollers and a given spindle speed, the amount of twist inserted cannot differ appreciably as between one considerable length of yarn and another. This has been confirmed by the present series of tests as discussed more fully on pages T293-T296. It is for this reason that in twist-testing at the Technological Laboratory the tests are made on a number of successive lengths of yarn.

No theoretical frequency-curves have been fitted to the frequency-polygons, as it is only in a few cases that the number of tests can be regarded as having been sufficient to make this justifiable. In drawing conclusions from our results, therefore, we have used our raw data, from an analysis of which we have obtained Table IV, showing the probability that a mean will lie within certain percentage limits of difference on either side of the mean for the single and twofold yarns respectively.

Table IV

Probability* of the Mean Twist exceeding certain Limits of Difference from the Mean

Counts of yarn	Number of individual test-values in set	Probability that the difference on either side of the mean, expressed as a percentage of the mean, will be less than					
		1%	2%	2·7%	3·3%	5%	10%
20	10	0·27	0·38	...	...	0·70	0·97
20	20	0·37	0·55	...	...	0·97	1·00
20	50	0·50	0·75	...	..	1	1
20	100	0·70	0·80	...	...	1	1
20	200	0·70	1	...	...	1	1
30	10	0·17	0·32	0·40	...	0·58	0·87
30	20	0·37	0·40	0·53	..	0·87	...
30	50	0·33	0·83	0·83	...	1	...
40	10	0·12	0·22	...	0·47	0·67	0·92
40	20	0·23	0·47	...	0·60	0·83	...
40	50	0·50	0·75	...	0·92	1	...
2/40's	10	0·70	0·84	...	...	1	1
2/40's	20	0·77	0·92	...	..	1	1
2/40's	50	0·84	0·97	...	...	1	1
2/60's	10	0·23	0·88	0·96	...	1	1
2/60's	20	0·75	0·94	0·99	...	1	1
2/60's	50	0·91	0·99	1	...	1	1
2/80's	10	0·75	0·90	...	0·98	1	1
2/80's	20	0·85	0·95	...	1	1	1
2/80's	50	0·92	1	...	1	1	1

*NOTE—A "probability" 1 represents certainty; a probability 0·5 represents an even chance; a probability 0·75 means that the chances of the event happening are 75 out of 100, or in other words the odds are 3 to 1 in its favour. Other values of the probability may be similarly interpreted.

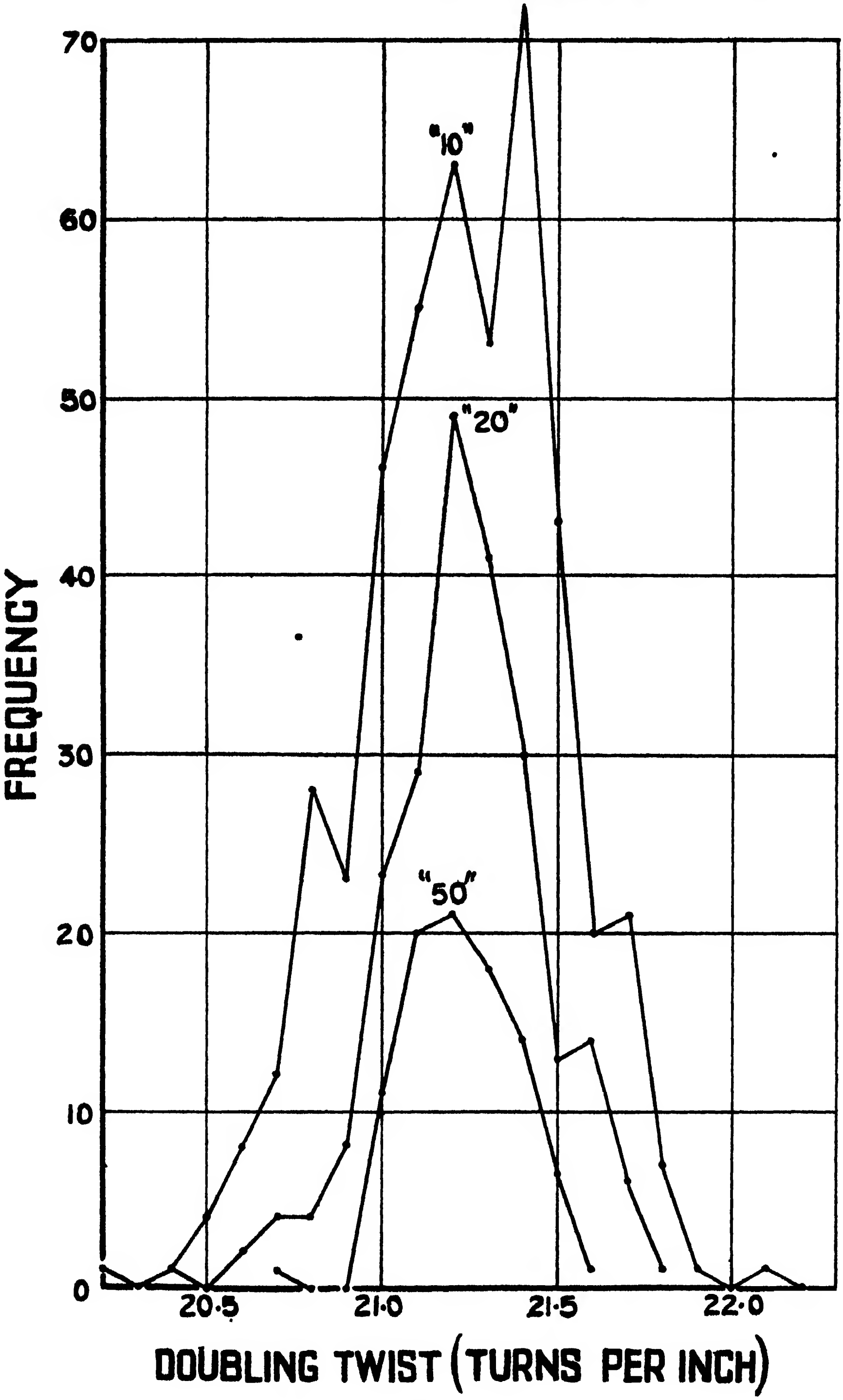

FIG. 7

Frequency-distribution of mean twist-values for sets of 10, 20, etc , for 2/60's.

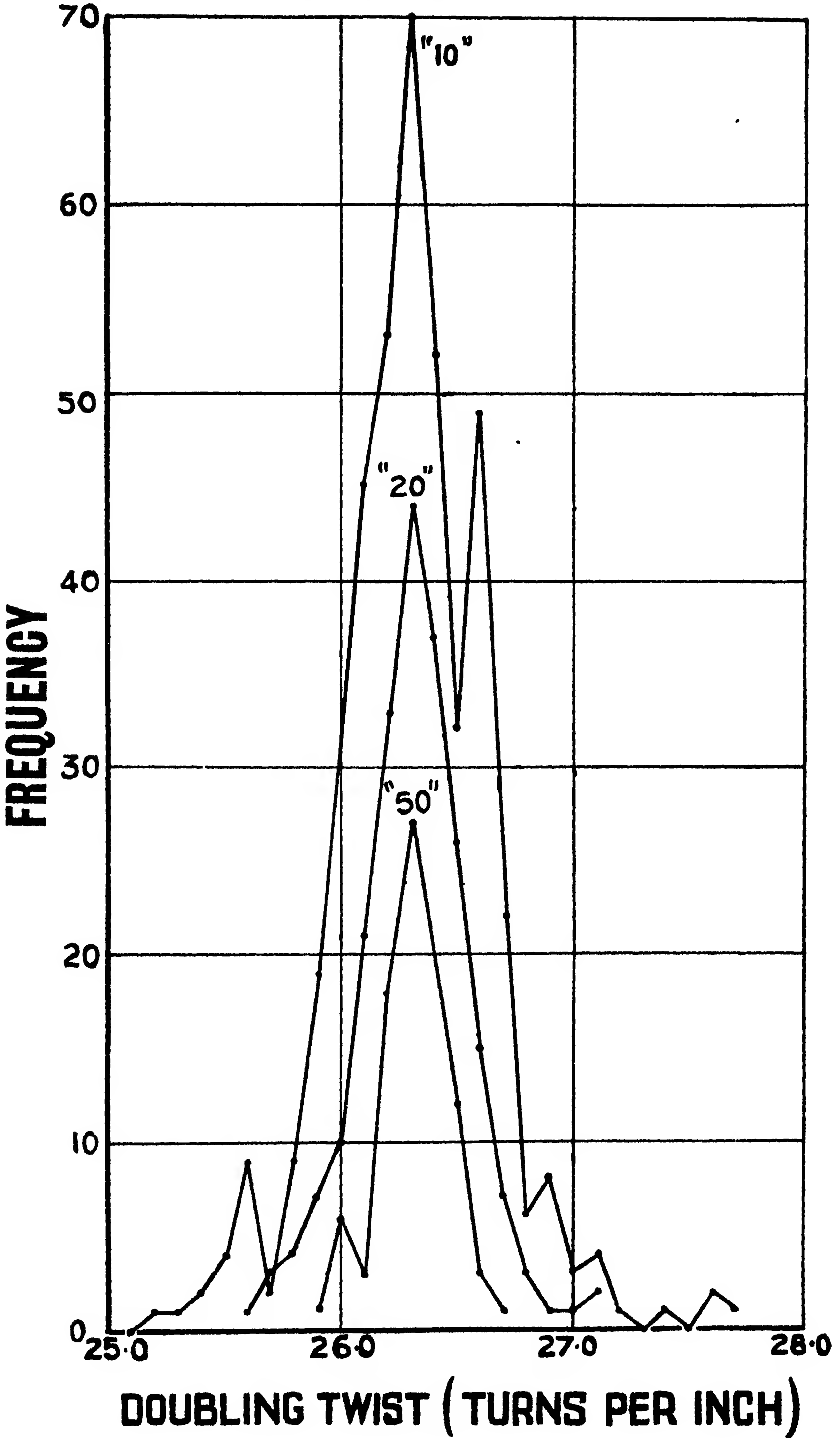

FIG. 8

Frequency-distribution of mean twist-values for sets of 10, 20, etc., for 2/80's.

We may briefly summarise these results for the 20's, 30's, and 40's counts, by saying that in the case of the single yarns we need to make 100 observations in order that the odds may be 5 to 1 that our mean value is correct within 2% on either side of the mean; whereas with the twofold grandrelle yarns we need to make only 10 determinations of twist on 10 in. lengths in

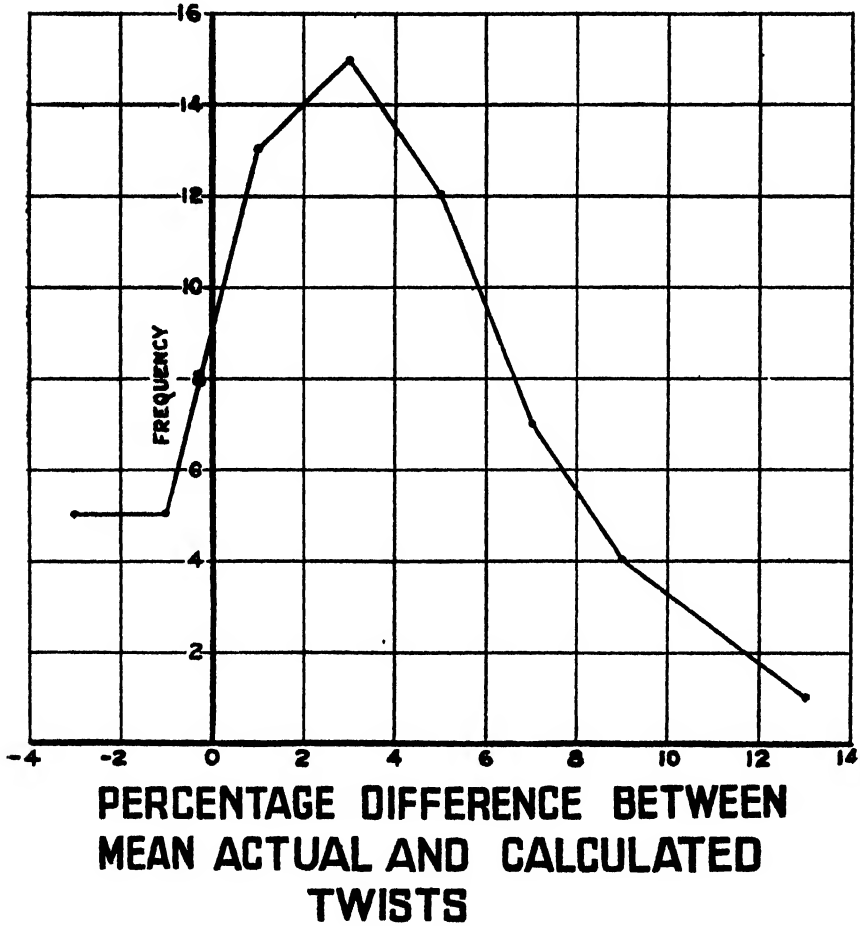

Fig. 9

Frequency-distribution of differences between mean actual and calculated twists in single yarns.

order that the odds may be 10 to 1 that our mean value is correct within the same limits.

In applying these results to checking whether the correct twist wheels have been used in spinning, it may be pointed out that an error of one tooth in the number of the twist wheel will make differences of 2·0%, 2·7%, 3·3%, respectively in the twist inserted in 20's, 30's, and 40's yarns. It

follows therefore that ten determinations of twist on 10 in. lengths of the grandrelle yarn are in practice sufficient to enable us to decide with a fair measure of certainty whether or not the correct twist wheel has been employed; and as it is the practice at the Technological Laboratory to make ten tests on each of 10 bobbins, the twist in all of which is governed by the one twist wheel, we have 100 twist tests available to enable us to check the correctness of the twist wheel in each spinning. In this case the checking is therefore carried out to a very high degree of certainty.

Actual and calculated twists in yarns—Results which have been obtained in 20,640 twist tests on ring spun single yarns, in counts ranging from 20's to 40's for 8 varieties of Indian cottons, show that the actual twist is higher than the calculated in about 9 cases out of 10, the difference between the actual and calculated values ranging from 9·4% to 0·4%, with an average value of 3·23% for the excess of the actual above the calculated twist per inch. The frequency-distribution of the percentage differences between the calculated twist and the means of sets of 160 (sometimes 200) tests is shown in Table V and Fig. 9.

Table V

Frequency-distribution of the Differences between Mean-actual and Calculated Twists in Single Yarns

Range	Frequency	Range	Frequency	Range	Frequency
−4 to −2	5	2 to 4	15	8 to 10	4
−2 to 0	5	4 to 6	12	10 to 12	.
0 to 2	13	6 to 8	7	12 to 14	1

Somewhat similar results were obtained by English[1], and from his figures for 20's, 30's, and 40's counts we see that the actual twist is higher than the calculated in about 7 cases out of 10. The excess is no doubt largely due to the fact that the length of roving delivered by the front rollers exceeds the length wound on to the bobbin owing to the contraction (milling-up) resulting from the insertion of twist in the yarn.

This matter has been investigated in the following manner—The delivery of the front rollers was calculated for one revolution of the cam of the builder motion and found to be 309·4 in. Knowing the actual twist in the yarn from our twist determinations and comparing it with the calculated twist, we find that, in order to explain the discrepancy, there should be contractions of 6·3%, 4·3%, and 2·8% in the 20's, 30's, and 40's counts respectively. Now in testing the 2,000 successive inches of 20's, and the 600 successive inches of 30's and 40's, a note was made of the position of the reversal point of the last coil at the apex of the chase; and the number of inches taken for testing before returning to this point was also noted, this being the total number of inches of yarn corresponding to the delivery of the front rollers for one revolution of the cam builder motion. It was found that on the average 299·4, 298·6, and 300·4 in. were necessary for this purpose for the 20's, 30's, and 40's counts respectively, instead of the 309·4 in. calculated. Hence the actual percentage contractions were 3·2%, 3·5%, and 2·9% for the respective counts. Thus only in the case of the 40's yarn does the value

agree with that deduced from the discrepancy between the actual and calculated twists in the yarn, the value for 20's being only about one half the contraction calculated from the twist values. The differences for the 20's and 30's counts may be due to (1) erroneous assumptions in the calculation of the twist constants, in which an arbitrary allowance is made for the thickness of spindle bands and for band slippage; (2) the tension to which the yarn is subjected during the spinning; (3) experimental errors.

Some measurements relating to possibility (1) are given in the Appendix. As regards possibilities (2) and (3), Table VI summarises the results obtained for the percentage contraction for a number of different cottons.

Table VI

Percentage Contraction of Single Yarns during Spinning resulting from the Insertion of Twist

Cotton	Position of yarn on the bobbin	Weight of traveller in gms for spinning counts			Actual percentage contraction in length on 309·4 in for counts		
		20 s	30's	40's	20's	30's	40's
P. A 285F ...	After the formation of chase ...	0·5386	0·3796	0·2577	3·23	3·50	2·90
Cambodia ..	At the completion of bobbin ..	0·5386	0·3796	0·2577	3·10	3·10	4·33
Dharwar ..	,, ,,	0·5386	0·3796	0·2577	3·39	4·72	2 49
1027 A L. F .	,, ,,	0·5386	0·3796	..	3·04	2·56	...
P A. 4F .	,, ,,	0·5386	...	.	3·10	.	..
Mixing of different varieties of Indian cotton ...	At the chase formation .	0·5386	.	.	0·44	..	..
,, ,,	,, ,,	0·3456	...	.	1·18	...	...
,, ,,	At the completion of bobbin ...	0·5386	...	...	1·42	...	..
,, ,,	,, ,,	0·3456	..	...	3·46	...	..

In the spinning of these yarns the diameter of the rings was constant, and although bobbins of rather smaller diameter were used for the 20's counts than for the higher counts, yet the chief factors affecting the spinning tensions were the weight of traveller, the counts of yarn spun, the spinning speed, and the particular portion of the bobbin on which winding was taking place. The traveller weights were well adjusted to the counts, but, on account of differences in the spinning speeds, the yarn stress per unit area of cross section will have been some 20% higher for the 40's than for the 20's yarn, though the total spinning tension will of course have been much less for the 40's than for the 20's. But although in testing the yarns for twist they are all placed under the same initial tension, so that, comparatively speaking, the lower count yarns are subjected to much less stress per unit area of cross section than the 40's yarn, yet this difference is far too small to account for the discrepancies in the contractions of the 20's and 30's counts. It would therefore appear as if the discrepancies for these counts must rather be ascribed to the numerous experimental difficulties and the errors consequently introduced.

In the case of the twofold yarns, it was possible not only to make an accurate determination of the twist but also of the extension due to the removal of the twist, the latter representing the contraction due to the twisting. Table VII shows how the actual twist determinations from 3,200 readings in 20's counts, 4,600 readings in 30's counts, and 4,300 readings for 40's counts, on 10 in. lengths in each case, compared with the values of twist per inch calculated on the one hand from the constant dividend for twist and on the other from the speeds of the front roller and the spindles.

Table VII

Comparison of Calculated and Actual Twists in Single and Twofold Yarns

	20's	30's	40's
Calculated twist per inch (including allowance for the thickness of banding and 1% spindle band slip) from the constant dividend for twist	16·6	21·6	26·6
Calculated twist per inch from the speeds of front rollers and spindles	16·6	21·6	26·8
Actual turns per inch found in twofold yarns	16·4	21·2	26·4
,, ,, ,, single yarns	17 7	22·6	27·4

The actual turns per inch in single yarn are included in this table for purposes of comparison. It will be seen that there is quite a good agreement between the actual and the calculated doubling twists in the twofold yarns, although the actual values are in each case slightly on the low side. A similar comparison between the actual and calculated values for the grandrelle yarns spun for the determination of twist in the standard Indian cottons (1926–30) gives the results shown in Table VIII for the different counts.

Table VIII

Comparison of Calculated and Actual Twists for Different Counts of the Standard Indian Cottons, 1926-30

Counts	Number of Tests	Twist		
		Calculated	Actual	Percentage difference
10	2,200	12·63	12·27	2·85
12	400	13·92	13·45	3·38
14	800	15·08	14·68	2·65
16	600	15·97	15 40	3·57
20	3,000	16·85	16·27	3·44
24	1,200	19·73	18·93	4·05
26	2,600	20·23	19·54	3·41
30	9,800	21·86	21·13	3·34
34	3,000	23·26	22·49	3·31
40	4,000	26 97	25·90	3·97

If we include also the results for certain other counts, we have no less than 52,800 test results available for comparing the actual with the calculated twists; from the 52,800 results it must be concluded that the allowance for thickness of bands and band slip is too small by 3·4% on the average, and that a total allowance for these two factors of 8·5% instead of 5% would give even more accurate results

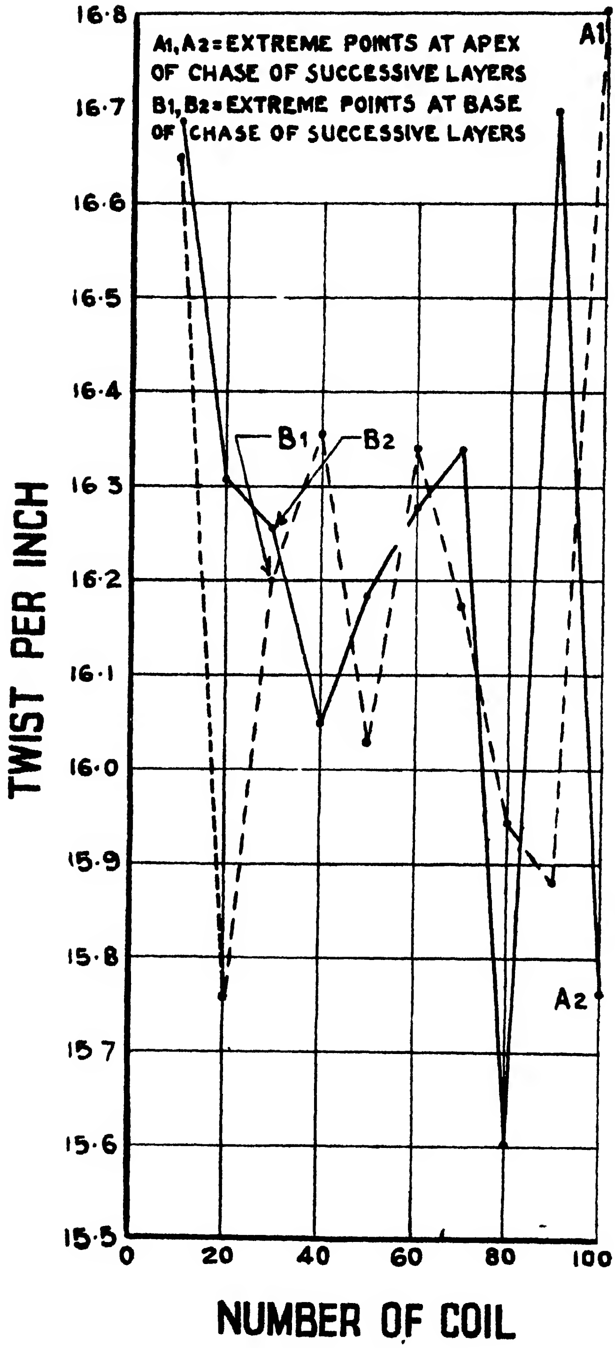

FIG. 10

Mean twist-values at different points of the chase of a bobbin.

The spinning of the grandrelle yarn having provided us with an accurate means of determining the twist in yarn, we have used it to investigate the following points—

(1) The variation of twist per inch due to variation in winding-on tension arising from differences in diameter of winding.

(2) The variation of twist per inch throughout the bobbin.

(3) The variation of twist per inch due to variation of count.

Variation of twist due to variation of winding-on tension—Theoretically, the traveller speed, which is derived from the spindle speed, and determines the amount of twist inserted in the yarn, is at its maximum at the base of the chase and at its minimum at the apex of the chase, with intermediate values in between. According to Nasmith[2], no such variation can be detected in the yarn. We have however tested the matter by determining the twist in one in. lengths of ten consecutive coils of the grandrelle yarn; the mean twist per inch in each set of 10 coils was then calculated. The results are plotted in Fig. 10, and show the average twist-values at different points of the chase for one complete revolution of the cam of the builder motion. It is evident from the results shown in these curves that any effect of a difference in the winding-on tension may be completely masked by irregularities due to other causes, such as irregularities in roving or re-adjustment of twist during the testing of the yarn.

(ii) *Variation of twist throughout the bobbin*—We have already seen that even when we take the mean values of successive sets of ten or more test values, the range of the means is quite considerable even in the case of the twofold yarns; thus, from Table III we see that the ranges of the means for sets of 10, representing the twist in 100 successive inches of twofold yarn, are 15·7–17·2 for 2/40's, 20·2–22·3 for 2/60's, and 24·8–27·7 for 2/80's; thus the range is roughly some 10% of the lower value. As might be expected, the range contracts as the length of yarn increases, as shown by the contracting range for sets of 20 and 50 test values respectively. The question may be asked, to what is the variation in twist between long lengths of yarn due? Now, as already pointed out, if the front roller speed and the spindle speed are constant, the amounts of twist inserted in successive lengths of yarn must be the same, except for differences in extension of the yarn caused by variation in the winding-on tension. Differences of twist between long lengths, therefore, must either be due to the variation in the winding-on tension as the bobbin fills, or to differential variation in the front roller and spindle speeds; obviously, if the speeds of both varied proportionately in the same direction, as would be occasioned by a drop in the main shaft speed owing to a reduced motor speed arising from a fall in the voltage, there would be no differences in the average twist per inch in long lengths. Such differences must be due to variations either in the winding-on tension or in the transmission of the tin roller speed by the spindle banding. The latter can only arise from a variation in the tension of the spindle banding, causing differences in band slippage; in order to ascertain whether these differences are serious throughout the whole length of yarn on a bobbin, we have grouped the test results in successive sets of 100, so that the mean values represent the average numbers of turns of twist per inch in lengths of 1000 in. each. The results obtained are shown in Tables IX, X, and XI.

Table IX

Mean Twist Values for Successive Sets of 100, 200, 400, and 800 Individual Tests on 10-in. Lengths of 2/40's

16·80	16·64	16·48	16·52	16·16	16·35	16·27	16·35
16·75	16·73	16·51	16·46	16·34	16·43	16·34	16·19
16·67	16·46	16·62	16·37	16·34	16·33	16·39	16·22
16·65	16·57	16·47	16·41	16·39	16·35	16·26	16·21
16·78	16·69	16·50	16·49	16·25	16·39	16·31	16·27
16·66	16·52	16·55	16·39	16·37	16·34	16·33	16·22
16·72	16·61	16·53	16·44	16·31	16·37	16·32	16·25
16·67		16·49		16·34		16·29	
16·58				16·32			

Table X

Mean Twist Values for Successive Sets of 100, 200, 400, and 800 Individual Tests on 10-in. Lengths of 2/60's

21·32	21·31	21·21	21·23	21·36	21·24	21·23	21·20	21·38	21·14	20·99	21·04
21·27	21·37	21·32	21·35	21·06	21·25	21·20	21·37	21·30	21·20	20·94	21·19
21·30	21·33	21·23	21·08	21·35	21·28	21·16	21·26	21·19	21·11	21·03	...
21·19	21·56	21·18	21·21	21·12	21·20	21·26	21·25	21·04	21·15	21·16	...
21·30	21·34	21·27	21·29	21·21	21·25	21·22	21·29	21·34	21·17	20·97	21·12
21·25	21·45	21·21	21·15	21·24	21·24	21·21	21·26	21·12	21·13	21·10	...
21·28	21·40	21·24	21·22	21·23	21·25	21·22	21·28	21·23	21·15	21·04	
21·34		21·23		21·24		21·25		21·19			
21·29				21·25							

Table XI

Mean Twist Values for Successive Sets of 100, 200, 400 and 800 Individual Tests on 10-in. Lengths of 2/80's

26·24	26 24	26·41	26·14	26·18	26·27	26·41	26·43	26·23	26·35	26·10
26·29	26·50	26·38	26·22	26·39	26·34	26·37	26·46	26·48	26·37	26·21
26·61	26·29	26·25	26·28	26·06	26·16	26·16	26·27	26·30	26·34	26·42
26·20	26·27	26·39	26·43	26·29	26·32	26·51	26·34	26·26	26·31	...
26·27	26·37	26·40	26·16	26·29	26·31	26·39	26·45	26·36	26·36	26·16
26·41	26·28	26·32	26·36	26·18	26·24	26·34	26·31	26·28	26·33	...
26·34	26·33	26·36	26·26	26·24	26·28	26·37	26·38	26·32	26·35	
26·34		26·31		26·26		26·38		26·34		
26·33				26·32						

In these tables the first result shown at the left hand top corner is the average value for the 1000 in. at the top of the bobbin, the second value, immediately below it is the average value for the next 1000 in.; and so on for the third and fourth values below; the fifth value, representing the average twist per inch in the fifth 1000 in., is shown immediately to the right of the first value, the sixth, seventh, and eighth values being placed successively below the the fifth; the value for the ninth 1000 in. is shown to the right of the fifth, and so on throughout the whole of the bobbin for the 32 successive 1000 in. of 20's, 46 successive 1000 in. of 30's, and 43 successive in. of 40's. In the fifth and sixth lines of each table are given the values obtained by taking the averages of the two successive pairs above them, so that the values in the fifth and sixth lines represent the average values of successive 2000 in. taken in order similarly to the values of 1000 in. In the seventh line are given the average values for successive 4,000 in., obtained by similarly combining the pairs of values for the 2,000 in. In the eighth line the values for the 4,000 in. are similarly combined to give four average values for successive 8,000 in., and these in turn are again combined in pairs in the ninth line to give the two values for the 16,000 in. comprising the top and the bottom of the bobbin respectively.

An inspection of these results shows that in the case of the 2/80's yarns there is the same average twist in the top and bottom halves of each bobbin; and on analysing the results for the quarters, eighths, and sixteenths of the bobbin, we find that similarly there is no regular variation in the distribution of the twist, low and high values for each 1,000 in. occurring almost indiscriminately throughout the whole of the bobbin. We therefore conclude that in this case the effect of any variation in the winding-on tension is negligible, and that the spindle band tension has been subject to certain variations which have occurred independently of the position of winding-on to the bobbin.

In the case of the 2/60's yarns there is again a close similarity between the average values for the top and the bottom halves of the bobbin, except that there is a slight tendency for the bottom of the bobbin to have rather less twist, as shown by the last two columns of Table X; this is made clear by an inspection of the values for the successive 4,000 in. of yarn, from which it will be seen that the values for the last two sets of 4,000 in. and the one set of 2,000 in. at the bottom of the bobbin are rather less than for the other nine sets of 4,000 in. each. In this case therefore the winding-on tension, being high in the formation of the bottom of the bobbin, may have been responsible for the lower values of twist there; but this hardly appears probable, if we bear in mind the result for the 40's yarn. The effect may have been to the spinning of this portion having occurred when the spindle bands were slacker, though we have no evidence that this was the case; indeed, it seems unlikely to have been so, seeing that there was no appreciable change in the humidity before and during the spinning of this yarn.

The greatest divergence is displayed by the results for the 2/40's yarns. In this case we see that the average twist in the top half of the bobbin is greater than that in the bottom half, and that the average twist decreases in each quarter of the bobbin from the top quarter to the bottom quarter; the eight successive lengths of 4,000 in. each show the same feature, although the fifth 4,000 in. is anomalous in giving a somewhat low result (16·31); the four successive 1,000 in. comprising each complete length of 4,000 in.

are somewhat irregular. Hence it would appear that in this case the spindle band tension has gradually increased, though once again we find that this cannot have arisen from a change in the humidity, which suffered no appreciable change before and during the spinning of the yarn.

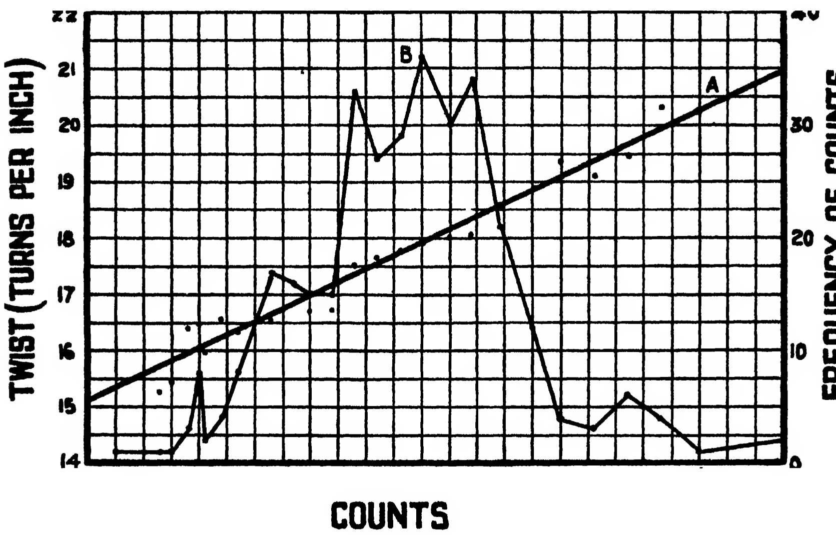

FIG. 11

A = Mean twist at various mean counts;
B = Frequency-distribution of counts along the length of a 20's singles yarn.

(iii) *Variation of twist due to variation of count*—The variation of twist due to variation of count has been investigated by weighing a 20's single yarn in successive lengths, each 6 in. long after the twist had been determined in each of the six inches. After the grouping according to the values of counts, the average twist was determined for each count group, giving the relation between twist and count shown in Fig. 11; in the same figure is also given the frequency-distribution of the counts of the 6 in. lengths. The straight line through the points representing twist at a given count has been drawn by the method of least squares. The correlation coefficient has been calculated between the two properties, twist and counts, and is as high as 0·655. This value, being based on 333 pairs of values, is certainly significant; moreover its high value indicates that the variation of count is the most important factor causing variation of twist, the position of the ring rail during winding on different parts of the bobbin, and the variation in traveller speed, being of subsidiary importance.

IV—CONCLUSIONS

The following are the conclusions arrived at from the results of the present tests—

(1) When single yarns are tested for twist by the ordinary method it is necessary to make at least 100 observations on 1 in. lengths in order that the odds may be 5 to 1 that the mean value is correct within 2% on either side of the mean.

(2) When a grandrelle yarn is made above a single yarn on the same bobbin by doubling together two single yarns, under the same spinning

conditions as those employed in the spinning of the single yarn, only 10 determinations of twist in 10 in. lengths need be made on the grandrelle yarn in order that the odds may be 10 to 1 that the mean value is correct within 2% on either side of the mean.

(3) The practice at the Technological Laboratory of making ten tests on the grandrelle yarn spun at the top of each of 10 bobbins enables the checking of the correctness of the twist wheel to be carried out to a very high degree of certainty.

(4) While the insertion of twist leads to a contraction of the yarn during spinning, this may be partly offset by an extension due to the effect of the winding-on tension.

(5) In calculating the twist per inch in the yarn from the "constant dividend" for twist, the allowance which is made for the thickness of the spindle bands and band slippage should be 8·5 per cent.

(6) Any effect on the twist per inch of a difference in the winding-on tension at the apex and base of the chase appears to be completely masked by irregularities due to other causes.

(7) Very little variation should exist in the total twist of successive long lengths of yarn wound on the bobbin, where such differences do exist they indicate the existence of variation either in the winding-on tension, or in the spindle band tension during spinning.

(8) The variation of twist in successive 6 in. lengths of yarn is chiefly conditioned by the variation of count along the yarn.

APPENDIX—ACTUAL AND CALCULATED SPINDLE SPEEDS

A number of tests have been made with a view to ascertaining how the average spindle speed, as determined by means of a tachometer, compares with the calculated twist. In the calculation of twist some allowance is usually made for the thickness of the spindle bands and for the band slippage. Some machinery makers advise adding 1/16th of an inch to the diameters of the spindle warve and tin roller to allow for both of these effects; other machinery makers advise the subtraction of 5% from the calculated value to allow for the loss of twist due to these causes. Mills[3] gives the following figures obtained by him for different counts from a few good mills—

	14's	21's	24's	28's	30's	32's
Calculated spindle speed (ignoring thickness of banding and slip), r p m	8,256	7,582	8,541	8 541	8,541	8,541
Observed or indicated spindle speed, r p m	7,354	6,700	7,952	7,952	7,752	7,741
Percentage allowance for spindle band thickness and slip	12·3	13·1	7·4	7·4	10·2	10·3

Some experiments on the subject have been made at the Technological Laboratory by determining the number of revolutions of the front roller of the ring frame by means of a Jacquet speed indicator, and simultaneously taking readings of the spindle speed by means of a Jacquet tachometer. The speed indicator was kept continuously in operation throughout a period of three minutes, during which the speeds of 24 spindles were obtained in turn with the tachometer. Observations were taken under spinning conditions for 20's, 30's, and 40's yarns. The ring frame is driven from a shaft which is motor driven; observations of the voltage and current during the testing

showed that these did not fluctuate appreciably. The frame was in a normal condition of lubrication, and tension of spindle banding, the spindles having been oiled a fortnight previously, and no bands having been allowed to remain on the frame for more than 12 days. The thickness of the banding when in a stretched condition and in contact with the tin roller, was 1/16th in. The following table summarises the results obtained—

Particulars	Counts of Yarn		
	20's	30's	40's
1—Number of spindles tested	24	24	24
2—Observed front roller speed, r.p.m.	198	160·7	133·5
3—Tin roller speed (calculated from the observed front roller speed), r.p.m.	966	1,019	1,042
4—Calculated spindle speed (excluding allowance for banding and slip)	9,660	10,190	10,420
5—Calculated spindle speed (allowing $\frac{1}{16}$ in. for thickness of banding), r.p.m.	9,149	9,647	9,870
6—Actual mean spindle speed, r.p.m.	9,048	9,564	9,837
7—Maximum spindle speed, r.p.m.	9,125	9,650	9,925
8—Minimum spindle speed, r.p.m.	9,000	9,450	9,725
9—Extreme variation percentage in observed spindle speed	1·38	2·09	2·03
10—Percentage increase of calculated spindle speed over observed spindle speed (ignoring allowance for thickness of banding)	6·76	6·54	5·93
11—Percentage increase of calculated spindle speed over observed spindle speed (including allowance for thickness of banding)	1·12	0·86	0·33
12—Turns per inch calculated from the observed speed of the front roller and spindle speed	16·62	21·62	26·79
13—Turns per inch calculated from the "constant dividend for twist" (allowing $\frac{1}{16}$ in. for banding and 1% for slip)	16·64	21·58	26·62

It will be seen from this table that allowing 1/16th in. for thickness of banding and 1% for band slippage has brought the results calculated from the observed front roller and spindle speeds into line with those calculated from the constant dividend for twist, allowing for the thickness of bands and band slippage. As shown in the present paper, however, it is desirable to allow rather more for the effect of these two factors, viz., 8·5% instead of 7·2%, in order that the results obtained for the actual determination of twist may coincide with those obtained by calculation.

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[2] Nasmith, J. "The Students' Cotton Spinning," 1918, pp. 528-531.
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TECHNOLOGICAL LABORATORY
BOMBAY
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17—SOME RESULTS OF CROSS-SECTIONAL AREA AND CONTOUR MEASUREMENTS OF NEW ZEALAND ROMNEY AND CORRIEDALE WOOLS

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The Wool Research Committee of the New Zealand Department of Scientific and Industrial Research, acting in co-operation with the Wool Industries Research Association, decided that in connection with wool research in New Zealand a collection of representative Corriedale and Romney fleeces should be sent to Torridon, for both trade opinion and laboratory examination.

The Romney fleeces were collected in the North and the South Islands, and the Corriedale fleeces from the South Island. A total of one hundred and ten fleeces was submitted. In the case of the North Island fleeces, the breeder is designated by a Letter in the accompanying tables and the various fleeces by a Number, while in the case of the South Island wools a Number has been used for the breeder and a Letter for the fleeces It should be noted here that whereas the North Island fleeces were selected for evenness, the South Island fleeces were selected to show the different types of wool present in the various flocks

It was decided that the first test should be of a commercial character, and a trade opinion was obtained on each fleece. The commercial report on these fleeces stated that the majority were very good, a few were only fair, and that taking the fleeces as a whole they represented a class above the standard of the average New Zealand crossbred wool. This examination enabled the fleeces to be divided into three groups—

Group I —Very good according to trade opinion.

Group II – Medium ,, ,, ,,

Group III—Fair ,, , ,,

and representative fleeces were selected from each group. From each selected fleece a moderate size shoulder sample was taken for the purpose of the laboratory examination. For purposes of measurement as detailed in the accompanying tables, this main sample was subdivided into sixteen zones by successive division and from each zone a small lock of wool was selected. From these small locks approximately even bundles of fibres were carefully separated off and were grouped together according to the number of sections it was necessary to cut. The resulting composite bundles were washed in ether to remove grease and dirt, and were then gently combed to straighten the fibres prior to embedding in collodion and paraffin wax by the method described by Barker and Burgess.[1] The section cutting and measurement of the fibres was also carried out as described in that publication, and the results obtained were treated statistically by the method outlined by Fisher.[2] The coefficient of variation was determined by use of the formula—

$$\text{Coefficient of Variation} = \frac{\text{Standard Deviation} \times 100}{\text{Mean cross-sectional area.}}$$

Table I. Romney Fleeces.

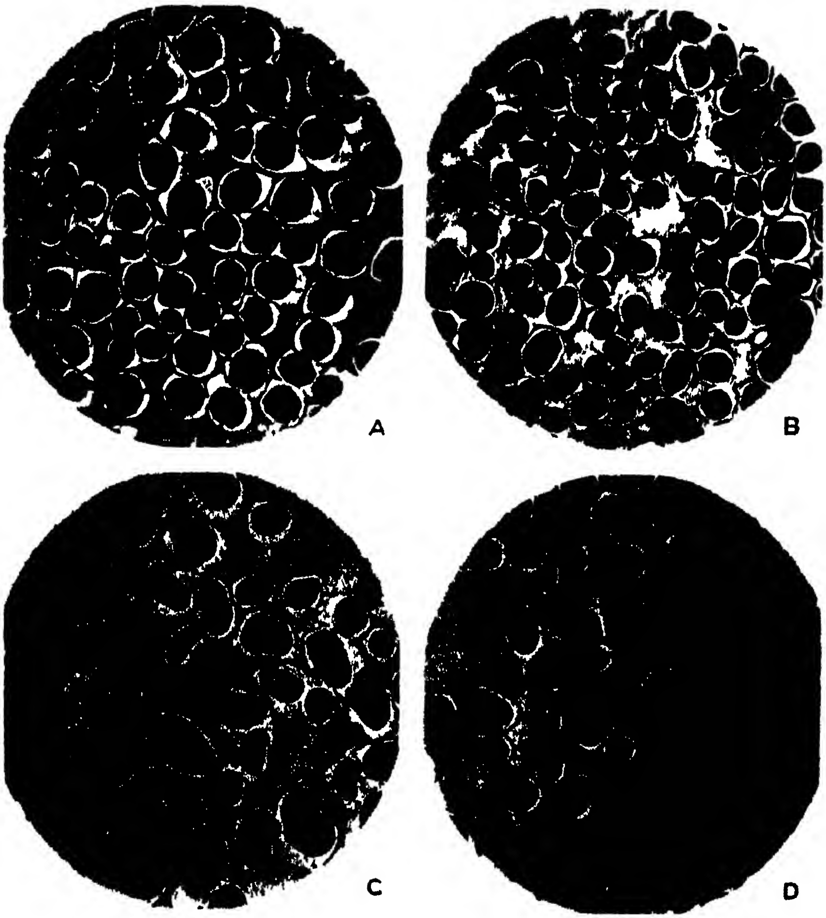
Group	No.	Mean cross-sectional area × 10^{-6} sq cm	Standard Error =	Coefficient of Variation	Smallest cross-sectional area	Greatest cross-sectional area	% Fibres < ½ mean cross-sectional area	% Fibres > 3/2 mean cross-sectional area	Contour A/B	% Fibres < 1·10 A/B	% Fibres > 1·40 A/B	Greatest A/B	Mean A/B for group
I	22A	9·703	0·229	37·9%	2·40	17·86	7·3	8·4	1·220	23·1	11·9	1·65	
	24A	7·390	0·171	40·2%	1·95	16·50	11·7	11·7	1·155	35·7	3·0	1·60	
	A3	9·170	0·154	29·2%	2·40	16·77	5·3	4·0	1·132	43·1	1·7	1·70	
	B2	11·090	0·201	31·4%	1·82	23·03	6·3	5·0	1·155	39·3	4·3	1·57	1·157
	C1	16·387	0·343	36·3%	3·40	27·70	13·7	5·0	1·098	57·7	0·7	1·59	±0·017
	Tag 1	10·479	0·195	31·0%	3·40	20·25	4·3	7·2	1·185	30·4	9·3	1·85	
II	2B	7·756	0·219	49·8%	1·56	17·0	12·0	12·3	1·225	21·6	15·2	1·80	
	2C	7·128	0·172	41·3%	2·10	24·84	8·9	9·2	1·219	30·0	8·9	1·75	
	16B	12·604	0·245	33·8%	2·25	24·48	4·4	6·1	1·275	10·1	29·4	2·00	1·210
	D4	11·600	0·246	36·7%	2·89	25·01	7·0	10·7	1·207	25·0	8·0	1·66	±0·018
	Tag 2	7·460	0·186	45·0%	1·80	16·80	16·0	9·8	1·203	27·4	10·1	1·75	
	A1	10·427	0·203	33·8%	3·61	22·00	5·6	9·6	1·142	40·0	2·8	1·67	
III	16C	10·743	0·210	33·5%	3·40	23·65	3·4	5·1	1·203	23·2	8·2	1·75	
	24B	8·477	0·224	45·6%	2·40	23·37	14·7	13·3	1·246	15·0	17·7	1·75	1·245
	24C	11·397	0·205	29·6%	1·69	20·80	9 6	8·5	1·287	17·4	24·4	1·90	±0·024
	Average for all groups			37%					1·197				

Group I = Very good according to trade opinion
Group II = Medium " "
Group III = Fair " "

Table II. Corriedale Fleeces.

Group	No	Mean cross-sectional area × 10^{-6} sq cm	Standard Error	Coefficient of Variation	Smallest cross-sectional area	Greatest cross-sectional area	% Fibres < ½ mean cross-sectional area	% Fibres > 2 mean cross-sectional area	Contour A B	% Fibres < 1·10 A B	% Fibres > 1·40 A B	Greatest A B	Mean A B
I	6A	6·006	0·138	35·8%	2·38	13·95	2·6	9·8	1·213	19·7	7·8	1·61	
	17A	5·638	0·156	43·6%	1·82	18·00	7·6	12·4	1·176	30·4	5·6	1·69	1·199
	18C	5·554	0·124	33·4%	2·72	12·09	1·8	11·1	1·196	23·6	7·1	1·63	
	26A	5·914	0·153	40·7%	1·68	15·40	8·5	12·1	1·219	20·2	10·1	1·59	0·008
	27C	5·956	0·122	32·5%	2·40	14·06	1·6	12·4	1·192	23·2	6·0	1·61	
II	4A	7·494	0·149	29·7%	2·55	15·40	3·3	7·6	1·223	15·6	7·6	1·73	
	7B	6·286	0·103	25·7%	2·72	11·10	3·6	4·4	1·228	20·4	10·8	1·57	
	9A	5·364	0·156	42·2%	2·08	15·48	2·8	10·4	1·182	26·0	3·6	1·64	
	19C	6·495	0·159	34·4%	2·35	13·60	8·6	13·6	1·218	23·2	10·1	1·82	1·201
	21C	5·312	0·133	39·6%	2·24	15·48	8·4	12·4	1·201	17·6	5·2	1·53	0·012
	8A	5·986	0·159	42·4%	2·10	13·26	10·0	11·6	1·152	32·4	2·4	1·62	
III	18A	7·476	0·196	38·9%	3·00	16·17	4·8	14·3	1·273	15·2	22·9	1·72	
	18B	5·982	0·107	39·9%	1·95	14·96	5·6	11·2	1·238	19·2	12·8	1·61	1·224
	25B	8·340	0·181	34·4%	2·88	16·80	6·8	10·0	1·151	33·6	4·0	1·60	0·026
	26C	7·180	0·205	44·6%	2·08	24·96	7·2	10·4	1·234	15·2	14·4	1·62	
	Average for all groups			37·3%					1·206				

Group I = Very good according to trade opinion
Group II = Medium
Group III = Fair



A B C D

DISCUSSION OF RESULTS

In the above tables the results are arranged according to the grouping of the fleeces previously noted, and it will be observed that there is little relationship between the trade classification of the fleeces and the coefficient of variation of cross-sectional area or fineness in either the case of the Romney or of the Corriedale. It should also be noted that in the case of the Romney wools there are in most cases approximately equal percentages of fibres outside the limits of one-half and one-and-a-half times the mean cross-sectional area. In the case of the Corriedale wools, however, there is a distinct tendency towards a greater percentage of coarser than finer fibres outside these limits. This probably results from the present-day tendency of the Corriedale breeder to select towards a class of wool more nearly approaching the Merino rather than the Lincoln or the Leicester.

In the case of the figures for contour, it will be noticed that there is a close relationship between the trade conception of a good wool and the average contour or ellipticity figure for each group. This is particularly noticeable in the case of the Romney. The average figures for contour for each group were—

			Romney	*Corriedale*
Group	I	Very good according to trade opinion	1·157	1·999
,,	II	Medium ,, ,,	1·210	1·210
,,	III	Fair ,, ,,	1·245	1·224

These figures are in accordance with the opinion expressed by Barker and Burgess[1] that contour probably plays an important part in the spinning properties of a wool.

Probably one of the most pleasing features of this examination from the point of view of the New Zealand wool producer is that, although some of the Romney and Corriedale wools show marked irregularity of size and shape of the fibres, others show a fairly high degree of regularity. It is evident, therefore, that by a careful selection within the breeds for fibre regularity, made possible by modern research methods, it should be possible to improve existing flocks to produce a type of wool that would be most acceptable to the manufacturer. In the above tables, however, the average coefficients of variation and the average contour figures for fifteen stud Romney and fifteen stud Corriedale fleeces show practically equal figures. This would indicate that the Romney wool from some of the best stud flocks is moderately even and that, therefore, there should be every possibility of improving the crossbred wool by using well bred rams. It should be remembered that the wools examined in this case were stud wools. Manufacturers have based their criticisms mainly on the crossbred wools from New Zealand, and one of the reasons why the Romney crossbred wool has been condemned is because of the tendency this breed has to produce medullated fibres when badly bred. Although the cross-sectional photomicrographs taken in connection with this work showed a greater proportion of medullated fibres in the case of the Romney than in the case of the Corriedale, it would be extremely difficult to express the presence of these detrimental fibres as a percentage, since it is difficult to say how much medulla must be present to be harmful. In this connection it might be pointed out that one of the Romney wools that appeared to be free from medulla when examined with the naked eye, showed a fair proportion of fibres with a very fine medulla in the microphotographs. It would seem, therefore, that when more attention is paid to the careful

selection of stud Romneys, with the greatest uniformity of wool characteristics and an absence of medullated fibres, that a desirable type of wool will be produced.

It might also be pointed out here that in many of the cases where the trade opinion of the fleeces noted a particularly soft handle, it was subsequently found that the wool had a low contour figure, i.e. it more nearly approached the circular. Although the contour or ellipticity of the wool fibres is not the only factor that plays a part in the handle of a wool, it probably has a considerable influence on this factor.

Photomicrographs A and B respectively illustrate moderately even and regular Romney and Corriedale wools, while C and D respectively illustrate bad cases of irregularity in the Romney and in the Corriedale.

The author is greatly indebted to the Council of the Wool Industries Research Association for permitting the work to be done in the laboratories at Torridon; to Dr. S. G. Barker, Director of Research, for helpful advice; and to Mr. C. G. Winson and Miss A. L. Walker, without whose valuable assistance it would not have been possible to carry out the work.

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18—THE SULPHUR CONTENT OF SOME SOUTH AFRICAN WOOLS

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From a chemical point of view, wool is singular among the commercial products produced by our farm animals, on account of the large proportion of sulphur which it contains. Its sulphur content is considerably higher than that of such typical protein-rich products of animal origin as milk, eggs, mutton, beef, pork, etc.*

During recent years wool research workers have devoted much attention to problems bearing upon the sulphur content of wool. Thus the work of Rimington[2] and of Marston[3] has shown that practically the whole (95–99%) of the sulphur is present as cystine, one of the sulphur-containing amino acids of proteins. Since a fair average figure for the sulphur content of wool is 3·5%, this means that cystine comprises as large a proportion as 13·1% of wool keratin. Barritt and King[4] have analysed numerous samples of wool, derived from different breeds, for sulphur content, and have definitely established the fact that the sulphur content of wool is variable.

The cause of this variability still lacks satisfactory explanation—one can only speculate as to its reason.

In dealing with a biological substance such as wool, it becomes exceedingly difficult to determine the nature of this variation. Wool is a product of the living organism, and is therefore subject to genetic, nutritional, and pathological influences. Such factors as breeding, age, and sex of the animal must be closely considered before determining whether nutrition has any influence upon the cystine or sulphur content of the wool.†

The suggested importance of the sulphur content of wool from a manufacturing point of view may be summarised by the following quotation from Barritt and King[5]—"......its rôle in solidifying the primary plasmic material and in strengthening its chemical stability in proportion to the amount incorporated becomes feasible. This suggests a parallel with the variation in strength and elasticity of rubber vulcanised to varying degrees."

* Hahn and Goodridge,[1] "Sulphur Metabolism," give the following figures for these products—

Mutton	0·233% ..	(Table 284, p. 167)
Eggs	0·204% .	(do.)
Cows' milk sp. from ...	0·024% ...	(,, 211, p 124)
Pork	0·204% ..	(,, 51, p. 40)
Beef	0·237% ..	(do.)

† To illustrate the effect of age on the sulphur content of rabbits' wool, Hahn and Goodridge quote the following figures from Düring ("Sulphur Metabolism," p. 27, Table 26)—

Hair of rabbit—1 month	4·00%	...	3½ months	4·36%
2 months,	4·07%	...	4½ ,,	4·38%
2½ ,,	3·90%	...	5 ,,	4·39%
	4·21%	..	18 ,,	4·77%

The same authors found a significantly lower sulphur content in kemp, and suggest that a deficiency in sulphur stimulus favours medulla formation. Barker[6] further states that "wool is characterised by its high sulphur content, and it has been found that there is a direct correlation between sulphur content and spinning quality."

The problem of sulphur content in wool, therefore, becomes a most important one from the producer's standpoint; in the first place, as it affects the quality of his wool, and in the second, how the value of his pasture may be affected. Since it is generally accepted that cystine cannot be synthesised by animals from mineral sources of sulphur or nitrogen, the natural supply for the animals' demand must necessarily be in the form of cystine derived from vegetable proteins rich in cystine.

The late Professor T. Brailsford Robertson[7] emphasises the latter point in his publication on the "Utilisation of Sulphur by Animals" by a theoretical calculation in which it was shown that the loss of sulphur from the Australian soils amounts annually to 10,000,000 lbs. of sulphur, exported from the country in the form of wool.

Hence the question arises whether the continuous drain on the sulphur content from our soils will not lead to a general sulphur deficiency in our pastures which will limit their carrying capacity from a wool production point of view. On the other hand, Hart and Paterson[8] state that "the total sulphur trioxide precipitated at Madison, Wisconsin, with the rain, amounted in the five months, June to October 1910 inclusive, to 11·7 lbs per acre. The annual amount may tentatively be placed at from 15 to 20 lbs."

A solution of the problem of the variation in sulphur content from the genetic and nutritional points of view is therefore of primary importance to the wool producer.

The valuable data accumulated by Barritt and King in their analyses of various wools throw very little light on this aspect of the subject, since no mention is made by them of the history of the wools analysed, the time of shearing and the nutritional and climatic conditions being unknown.

It was with the object of obtaining some further data on this subject of the sulphur content in wool and with more especial reference to its biological and nutritional aspects, that an analysis was undertaken of various South African Merino wools which had been produced under known conditions

For the Merino wools analysed, the writer is greatly indebted to the Grootfontein School of Agriculture, and in particular to Messrs. G. Marec and L. Roux who conducted the animal experiments, the immediate object of which was to determine practical maintenance rations for Merino sheep during periods of drought. The sheep used in these experiments were all selected Merino Hamels (wethers) of uniform type and age (6 tooth), factors which exert an influence upon the production of a biological substance such as wool.

DESCRIPTION OF NUTRITIONAL AND OTHER CONDITIONS IN DIFFERENT GROUPS OF SHEEP

Group I consisted of six Merino fleeces grown under normal conditions of karroo pasture for a period of nine months. These sheep were shorn in March 1929, and again on the 4th of January 1930.

Group II—The five sheep from this group were shorn on the 27th November 1928, grazed on karroo veld until the 11th December 1928, then

being put in small paddocks in which shelters were placed containing feed troughs. These paddocks were absolutely free from vegetation. The sheep of this group were also shorn on the 12th December 1929.

The daily ration received by these sheep was as follows—

Period	...	11/12/28– 3/ 8/29	...	2 lbs. of crushed maize and water *ad lib.*
,,	...	4/ 8/29–12/12/29	...	1 lb. ,, ,, ,, ,,

Group III were kept under conditions identical with those of Group II, shorn at the same time, and received the following daily ration for the entire twelve months of the experiment—

3 lbs. of Oldman saltbush.
12 ozs. of maize and water *ad lib.*

All sheep of these groups had free access to a lick consisting of two parts of salt and one part sterilised bonemeal.

EXPERIMENTAL

In the analyses of these wools the shoulder wool only was considered. From each fleece the shoulder was carefully selected, divided into 32 zones, and a small sample from each zone taken for the bulk sample for sulphur analyses.

In the case of Groups I and II, small samples from each zone were also selected for an analysis of the cross-sectional area, and in the veld fleeces the fineness was also determined by the length per unit weight method, fully described by Roberts.[9]

The sulphur analyses were done by a modification of the Benedict Denis method recently described by Rimington.[10] Triplicate samples of each wool were analysed for sulphur. In any case where a difference greater than 0·006% (i.e. a difference greater than 1·6% of the amount determined) was found, the analysis was repeated.

The wool was thoroughly freed from any adhering matter by washing it twice in hot pure benzene, followed by a washing in 0·1% saponic solution and repeated washings in distilled water.

The wool was then allowed to dry. Before taking the samples for the sulphur and regain determination, the dry wool was thoroughly combed by means of two hand carding brushes, thereby ensuring that a thoroughly homogeneous sample was taken. The wool was then allowed to condition in a room of fairly constant humidity for a period of 24 hours. Two separate regain (moisture) determinations were made in conjunction with each sulphur determination. The procedure followed in regain determination was identical with that described by Barritt and King.[4]

NUTRITION AND SULPHUR CONTENT

In Table I the percentage of sulphur and regains of the wools from the individual sheep on the various rations are tabulated, together with a description of each wool.

An inspection of this table reveals the following points—

A considerable variation in the sulphur content in the wools from different individual sheep fed on the same diet. It would therefore seem at first glance that nutrition has no direct influence on the sulphur content of the wool of sheep identical in age, type, and sex. This suggests that the sulphur content of wool is an inherited character.

Table I

Group	Number of Sheep	Average % of Sulphur on Dry Weight	Regain	Trade Remarks on Whole Fleece
I (Veld fleeces) ...	193	3·56%	12·41%	Good soft handle, 64's quality.
	196	3·60%	12·98%	,, 60–70's quality.
	198	3·61%	12·84%	,, 70's quality.
	203	3·71%	14·65%	,, 64–66's quality.
	204	3·24%	14·97%	Fairly good handle, 60's quality.
	207	3·72%	13·59%	Good soft handle, 64–60's quality.
II (Maize-fed sheep)	1	3·90%	12·77%	Good handle but tender at tip, 64–60's quality.
	5	3·74%	15·03%	Very good handle but slightly tender at tip, super 64's.
	6	3·85%	14·01%	Good handle but tender at tip, 64's quality.
	7	3·37%	12·67%	Good handle—sound, 66–70's.
	9	3·70%	14·62%	Very good handle—sound, 70's.
III (Oldman saltbush and maize-fed sheep)	111	3·48%	14·27%	Good handle—sound, super 64's.
	112	3·30%	17·24%	Fairly good handle—sound, 60's.
	114	3·19%	15·40%	Good soft handle— sound, 64's
	116	3·06%	15·06%	Poor handle—tender—common, 64–60's

The results tabulated in Table II of analyses made along the length of the staple of various of the above wools throw an entirely different light upon the problem, however, and reveal the influences that nutrition has upon the sulphur content of wool.

In determining the sulphur content of the three different fractions, tip, middle, and root staples from each sample were selected and cut into three equal portions. Three sulphur determinations on each of these three fractions were carried out in exactly the same way.

Table II

Group	Number of Sheep	Fraction	Average Sulphur % on Dry Weight	Regain	Average Sulphur % for Three Fractions
I	203	Tip ...	3·66%	14·55%	3·70%
		Middle ..	3·63%	14·72%	
		Root ...	3·81%	15·29%	
	193	Tip ...	3·54%	14·26%	3·54%
		Middle ...	3·38%	10·47%	
		Root ...	3·71%	16·15%	
	196	Tip ...	3·62%	14·23%	3·59%
		Middle ...	3·44%	14·14%	
		Root ...	3·71%	14·68%	
III	111	Tip ...	3·52%	14·76%	3·49%
		Middle ...	3·48%	14·11%	
		Root ..	3·48%	14·00%	
	112	Tip ...	3·31%	15·53%	3·32%
		Middle ...	3·30%	15·52%	
		Root ...	3·35%	15·73%	

The figures obtained from the three veld-grown fleeces afford, perhaps, the most interesting data from a nutritional point of view. In each of these wools the sulphur content of the root fraction was invariably the highest, that of the middle fraction the lowest, whilst that for the tip fraction lay between these extremes. Before discussing the importance of this phenomenon, let us briefly consider the nutritional value of South African pastures throughout the year.

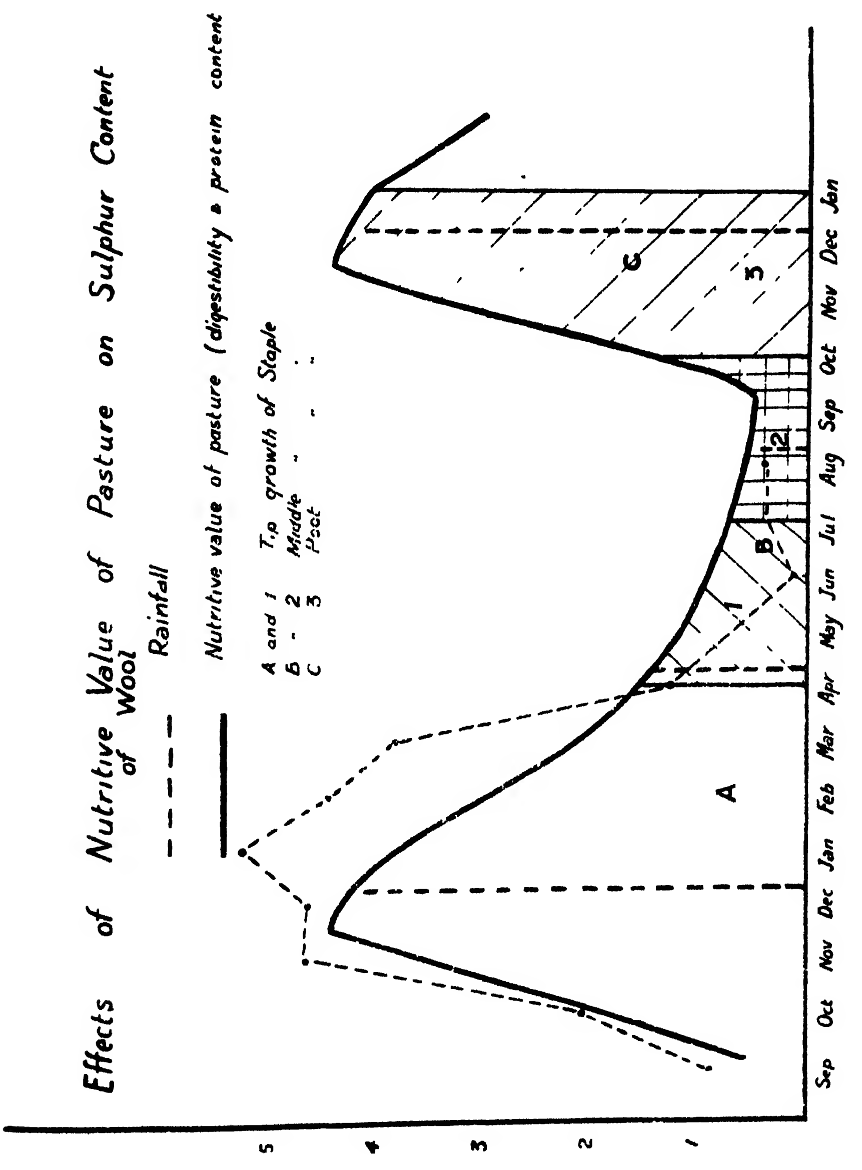

FIG 1

Fig. 1 gives a graphical illustration of the decline of the nutritional value of natural vegetation in the summer rainfall area (the sheep growing area) as

the season advances from the beginning of spring towards the end of winter. In the main sheep-growing country, 70–85% of the annual rainfall is precipitated during the spring and summer months. The average monthly distribution of rainfall in this summer rainfall area, as recorded by the Union Observatory over a period 1904–1929, is presented by the dotted line in Fig. 1. This graph clearly illustrates the great difference in the amount of rain precipitated during the summer and winter months respectively.

Shortly after the first torrential spring rains—which may be expected towards the end of September or during October in normal years—a rapid growth of young vegetation replaces the depleted and comparatively bare pasture. Within the next few weeks the pasture reaches a maximum digestibility and nutritive value, and of particular interest is the fact that its protein content also is then at its highest.

From this time onwards, although the amount of vegetation still increases, its digestibility and protein content rapidly decrease. Towards autumn and during the winter months the pasture becomes rapidly depleted. Sheep which are entirely dependent for their nutrition upon the vegetation of the pasture usually lose condition and weight during the latter period.

Staples and Taylor[11] give the following interesting account of the decline in nutritional value of pastures in South Africa—"Young pasture, as well as being rich in protein, has been shown to have a higher mineral content. The digestibility coefficient of the young grass is also exceedingly high, over 80% even of the fibre, and if the moisture content is disregarded the dry matter of young grass can be considered in the nature of a remarkably digestible concentrate with a narrow nutritive ratio of about 1–3. The mature herbage on the other hand has not only a far wider nutritive ratio of about 1–10, but also is much less digestible (a coefficient of about 50% as compared with 80 per cent.)."

"The percentage of crude proteins drops sharply as the herbage becomes older and more stemmy. The eight months' old veld grass only contains 2·96% of crude protein, as compared with 12·25% in the young stage."

Considering the figures for the three fractions of the veld-grown fleeces, it is remarkable how these correspond with the fluctuations in the value of the pasture. The three periods which these fractions represent are shown by the perpendicular lines in Fig. 1. From this graph it will be seen that the tip fraction represents the wool growth during the period in which the nutritive value of the pasture is in rapid decline.

The middle fraction corresponds to the period in which the pasture has reached its lowest feeding value, together possibly with the first few weeks after the spring rains (depending upon the date of the first seasonal downpour). The root fraction represents the growth which took place following the spring rains, i.e. at a time when the pasture was at its maximum feeding value. On the other hand, the figures for the sulphur content of the wool grown by that group of experimental sheep which was kept on a constant ration show no appreciable difference as between the middle and root fractions. The three periods of growth represented by the fraction from the experimentally fed sheep are represented by the dotted perpendiculars on the accompanying graph.

Considering the fact that it is customary in the principal sheep growing areas of South Africa and Australia to shear the flocks during September and October, the higher sulphur content found in the tip of the wools analysed

by Barritt and King is therefore susceptible to a precisely similar explanation, the tip fraction of their samples representing growth during the spring months of luxurious herbage.

The results for the total sulphur analyses of the fleeces produced by the sheep fed on a diet of maize only, are somewhat surprising. With the exception of fleece No. 7, these wools show a sulphur content normal for Merino wools. Maize is a cereal not only low in its protein content, but its proteins are also known to be deficient in certain of the amino acids, viz. tryptophan and lysine.

According to Hahn and Goodridge, maize contains 0·147% sulphur, and, as compared with other cereals, it cannot be considered as sulphur deficient.

It would therefore seem that the percentage of sulphur in wool is not so much influenced by the total percentage of protein in the diet as by the relative quantity of cystine supplied in the latter.

The above data seem to lead inevitably to the conclusion that, although the sulphur content of sheep's wool is largely an individual character inherent or inheritable, this characteristic figure may be altered by the operation of a certain set of environmental circumstances, such as, for example, limitation of the cystine supply in the natural diet. As long as the demand for cystine for the production of wool by the animal is adequately met by its nutritional intake, the wool produced will have the normal sulphur content, inherent for that animal. When, however, the supply becomes inadequate to meet the demand, a reduction follows in the sulphur content of the wool produced. This is similar to the case in the nutrition of rats studied by Lewis and Lightbody[12] in which feeding of adults upon a diet deficient in cystine was found to lead to a reversion on the part of such animals to the "puppy" coat notably poorer in sulphur, which is characteristic of the young rat.

From the figures quoted in this paper it is evident that such nutritional factors are operative upon sheep grazing under typical sheep farming conditions upon the South African veld (Karroo). The variation in the nutritive value of the pasture may be seen reflected in the varying composition of the wool grown during the different seasons.

No data are at present available to show whether with diminishing sulphur content there is also a diminishing production of wool in bulk.

An interesting line of research is hereby opened up which is of considerable economic importance since it may prove that limitation of sulphur supply is capable of influencing both sulphur content and actual weight of fleece produced during such a period.

SULPHUR CONTENT OF WOOL AND ITS RELATION TO CROSS-SECTIONAL AREA AND CONTOUR

The cross-sectional area and contour of the wools from Groups I and II were also analysed. The technique fully described by Winson[13] was followed in this determination. In addition to the South African Merino wools, data on the cross-sectional area, contour, and sulphur content of eight other wools from different breeds were also available.

The fineness expressed as length per unit weight was also available for the shoulder wool of Group I. Table III gives a summary of the results of these analyses.

The data accumulated in Table III should be regarded as preliminary and insufficient from which to draw any definite conclusions. The limited figures available, however, do not indicate any correlation between fineness

Table III

Group	Number of Fleeces	Average Sulphur Content	Cross-sectional area	Coefficient of Variation	Contour expressed as Major axis / Minor axis	Length per unit weight cm./mg
I Veld fleeces	193	3·56%	4·100	31·18%	1·217	275
	196	3·60%	3·607	37·82%	1·196	274
	198	3·61%	3·867	32·20%	1·181	254
	203	3·71%	3·737	39·35%	1·205	258
	204	3·24%	5·570	56·18%	1·214	186
	207	3·72%	5·157	33·75%	1·211	244
II Maize-fed sheep	1	3·90%	5·110	28·50%	1·202	
	5	3·74%	4·023	26·05%	1·170	
	6	3·85%	4·066	25·96%	1·206	
	7	3·37%	4·256	29·24%	1·199	
	9	3·70%	3·990	27·85%	1·195	
Other Wools	Southdown Tegs	3·43%	5·554	45·87%	1·226	
	Southdown Ewes	3·57%	6·814	48·16%	1·199	
	Shropshire Wethers	3·55%	12·164	34·85%	1·308	
	Shropshire	3 13%	7·430	37·17%	1·247	
	Half-bred Wethers	3·30%	9·558	33·43%	1·327	
	Kent Wethers	3·14%	9·538	41·60%	1·223	
	Irish Wethers	3 27%	13·740	31·99%	1·313	
	Lincoln Wethers	3 32%	15·114	33·18%	1 161	

or contour and sulphur content either within the same or irrespective of the breed. It is well-known from practical experience among sheep farmers in South Africa that during seasons of drought in which the pasture is poor and depleted, the wool tends to become finer. On the other hand, during good seasons the same sheep will produce a bulkier and stronger (coarser) fleece The influence of poor conditions of pasture on the sulphur content of wool has been mentioned in the first part of this paper—depleted pastures lower the sulphur percentage—and the figures quoted afford demonstration of the fact that, even under identical nutritional conditions, wools of different sheep may vary in sulphur content (inherent variability) just as they are known to do in fineness.

It is thus of great importance to realise when any attempt is being made to correlate sulphur content with fineness, that fineness itself is the resultant of two factors (inherent variability and nutritional conditions) just as is sulphur content, and that variations in the one factor, "nutritional conditions," operate in opposite directions in the two cases.

It should, however, be pointed out that in attempting to correlate fineness (as determined microscopically by cross-sectional area) and sulphur content, the area is determined only at one point along the fibre, and therefore does not represent a true average figure for the fibre along its total length, which may vary considerably in this respect. On the other hand, in the determination of the sulphur content, each fibre contributes according to

its weight. Fineness for comparison with sulphur content should therefore be determined by the method based upon length per unit weight.

Barritt, King, and Pickard[14] have recently published a paper dealing with a similar aspect of the subject of nutrition and sulphur content in rabbit wool. At first sight their results seem contradictory to those obtained by Lewis and Lightbody quoted in this paper, and to those recorded by the present writer. A closer examination of their results indicate, however, that they are still in accord with those found in this work, since the ration used in their feeding experiments was evidently not sufficiently deficient in cystine to influence the optimum inherent sulphur content of the wool.

No mention was made of the cystine content of the ration used, and the minimum cystine requirements for the production of wool with its optimum inherent sulphur content by the rabbit is still an unknown quantity as far as the writer is aware.

Adult rabbits were used and may vary considerably in age. The slightly increased sulphur content found by them in the second season's clip may, therefore, be due to the influence of increase in age as has been shown by Düring. Also, if their theory "that the sulphur stimulus under which keratinisation of the cells proceeds—we must presume by incorporation of the cystine nucleus into the protein structure is most active immediately after shearing" is correct—the higher figures obtained in the second season's wool may be explained by the fact that the period between the times of shearing of the first season was 105 days against 84 in the second.

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19—NOTE ON THE RELATIONSHIP OF FIBRE FINENESS AND WOOL QUALITY IN COMBED TOPS

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Quite recently a very interesting relationship has been found to exist between the average fineness of a standard English combed top and its position in the scale of qualities. The same relationship may also be shown to hold in principle for the French, German, Italian, and other Continental standards.

The values of fineness used to establish this relationship are those which have recently been published from this laboratory as the results of measurements on a range of tops which has been selected by the trade itself to contain typical qualities. These results are summarised in Table I.

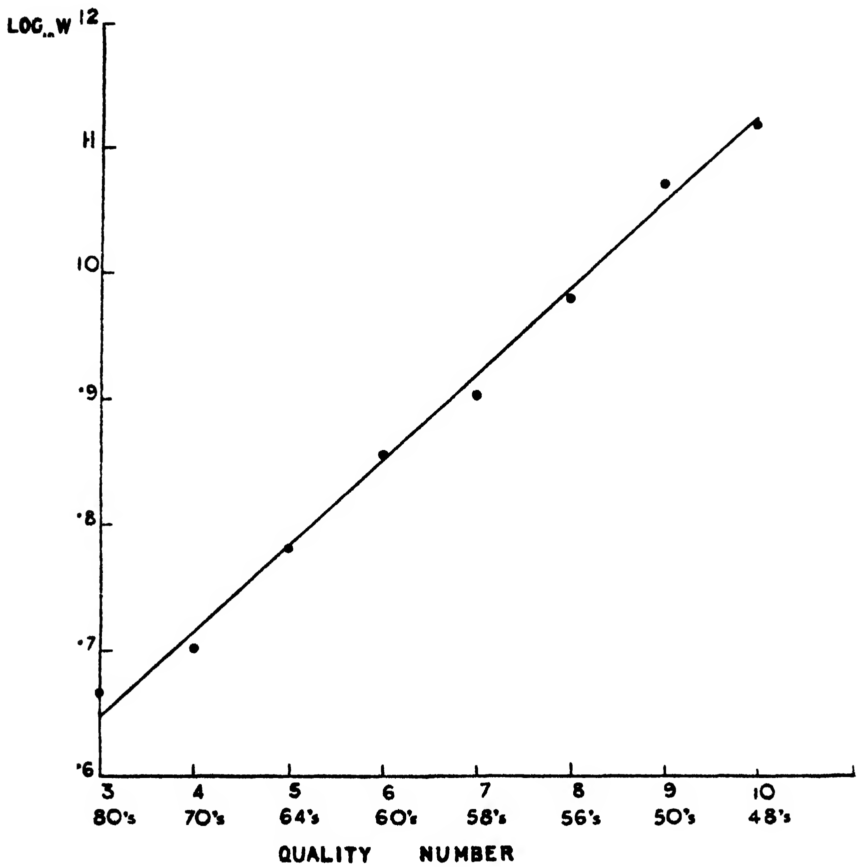


FIG I

It has been found that a linear relationship exists between the logarithm of the average fineness of a top, expressed as the weight of 10 metres of fibre, and its position in the scale of qualities when equal intervals are assumed

Table I

Quality	x	Weight in milligrammes of 10 metres of fibre at $18\frac{1}{4}\%$ regain. $\left(\frac{W}{L}\right)$	$\text{Log}_{10}\frac{W}{L}$
80	3	4·64	·6665
70	4	5·04	·7024
64	5	6·03	·7803
60	6	7·17	·8555
58	7	8 01	·9036
56	8	9·55	·9800
50	9	11·69	1·0679
48	10	13·10	1 1173
46	11	13·41	1·1274
44	12	15·25	1·1832
40	13	16·21	1·2098
36	14	15·71	1·1962

between these qualities. It is convenient to ascribe the numbers 10, 9, 8 . . . 2 to the qualities 48's, 50's, 56's . . . 80's, thus providing, if necessary, for two qualities above 80's. The relationship found is true from the highest down to the 48's quality. Fig. 1 shows the result of plotting the logarithm of the weight/length ratios of fineness against the position of the top in the scale of qualities according to the grade numbers above. The best values for the constants of the line passing through these points have been calculated by the method of least squares. It then appears that the relation between fineness and quality for British tops is expressible by the equation—

$$x = 14{\cdot}79 \log_{10} \frac{W}{L} - 6{\cdot}58 \qquad \text{(1)}$$

where the successive values of x, 10, 9, 8, etc., represent the qualities 48's, 50's, 56's, etc., and where $\frac{W}{L}$ is the weight in milligrammes of 10 metres of fibre taken at a regain of $18\frac{1}{4}$ per cent.

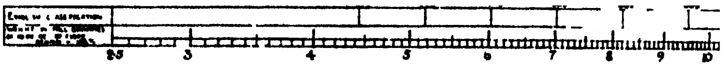
Equation (1) may also be written in the form—

$$\frac{W}{L} = e^{\frac{x-6{\cdot}58}{6{\cdot}43}} \qquad \text{(2)}$$

from which it is apparent that on substituting the successive values of x, namely, 3, 4, . . . 10, the scale of fineness becomes in reality a series of values in geometric progression with a constant ratio, $r = e^{\frac{1}{6{\cdot}43}}$.

Equation (1) is very useful. Once the mean fineness of a top is known its position on the English scale of standards may be readily obtained. Conversely, the mean fineness of any top conforming to the standards may be found by substituting the corresponding value of x The relationship expressed by the equation also lends itself very well to diagrammatic treatment. If the fineness readings are marked off on a logarithmic scale, the mean values for the different qualities will occur along a collateral scale at

equal intervals. It is thus quite easy to construct a fineness scale from which values can be read off instantly. (Fig. 2.)



SCALE OF FINENESS

FIG 2

In the coarser wools the presence of medullated fibres would, of course, render the weight/length method for measuring fibre fineness somewhat unreliable owing to variations in fibre density in such cases. Contour measurements would be more accurate for thickness determinations.

French Standards

The figures for French standards put forward by MM. Dantzer and Roehrich[1] after examination of a range of French tops are found now to conform to the same law as that expressed by equation (1), with, of course, a difference in the constants of the equation necessitated by a different nomenclature. MM. Dantzer and Roehrich have employed the numbers 17, 16, etc., to correspond to the French qualities 150, 140, etc., according to the following scale—

Table II

French Qualities	Quality Number (MM Dantzer and Roehrich) x	Weight in milligrammes of 10 metres of fibre at 18¼% regain $\frac{W}{L}$	$\text{Log}_{10} \frac{W}{L}$
150	17	2·52	·4014
140	16	2·93	·4670
130	15	3·39	·5307
120	14	3·91	·5920
110	13	4·47	·6507
100	12	5·19	·7155
P	11	5·97	·7756
I	10	6·89	·8383
II	9	8·02	·9043
III	8	9·31	·9688
IV	7	10·95	1·0396
V	6	12·96	1·1126
VI	5	15·48	1·1897
C	4	18·92	1·2770

Using these values in the same way as for the English tops, we have found that the relation between fineness and quality for French tops may be represented by the equation—

$$x = 23{\cdot}30 - 15{\cdot}77 \log_{10} \frac{W}{L} \qquad \text{.........................(3)}$$

This relation holds from the finest down to the IV's quality. In this equation x signifies the quality according to the nomenclature of MM. Dantzer and Roehrich and $\frac{W}{L}$ the weight in milligrammes of 10 metres of fibre taken at a regain of 18¼ per cent.

German Standards

Fineness figures in terms of the weight of 10 metres of fibre are as yet not forthcoming for approved German tops of different qualities. In the *Melliand Textilberichte* for July 1930, p. 516, Plail[4] publishes the following scale of finenesses obtained after numerous measurements had been carried out on raw wool and tops. His results are stated in terms of the average fibre width expressed in μ (Table III).

We have included in the last column of the table the common logarithms of the mean fibre width for each quality in order to show that when these are plotted against the qualities in the first column at equal intervals a straight

Table III

	Quality	Limits of mean fibre width in μ	Mean fibre width in μ	Logarithm of preceding column
1	4A	Below 16·5		...
2	3A	16·5—18·5	17 50	1 2430
3	2A	18·5—21·0	19·75	1·2956
4	A	21·0—24·5	22 75	1·3570
5	B	24·5—28·5	26 50	1·4232
6	C_1	28·5—32 5	30 50	1 4843
7	C_2	32·5—37·0	34 75	1·5409
8	D_1	37·0—42·5	39 75	1·5993
9	D_2	42·5—49 5	46 00	1·6628
10	E	49·5—59·5	54·50	1·7364
11	F	Over 59 5	.	...

line relationship is obtained, the finenesses of the range of qualities thus forming a geometric progression. Allotting to the qualities 4A, 3A, etc., the numbers 1, 2, etc., it may be shown that the relation between fineness and quality for German standards is expressed by the equation—

$$x = 16{\cdot}15 \log_{10} F - 17{\cdot}96,$$

where F represents the mean fibre width in μ and the successive values of x.—1, 2, 3, . . . 11, the qualities 4A, 3A, 2A, . . F.

Italian Standards

In view of the foregoing it is interesting now to consider the Italian standards put forward by Commander Schneider at the Bradford meeting of the International Wool Conference[6] in November 1929. He has suggested a fineness scale based upon a geometric progression. This scale is reproduced in Table IV. Finenesses are again expressed in terms of mean fibre width in μ.

Table IV

Finesse	Mean fibre width in μ	Log mean fibre width	Finesse	Mean fibre width in μ	Log mean fibre width
1	15·7	1 1959	14	27 0	1·4314
2	16·4	1 2148	15	28 2	1·4502
3	17·1	1·2330	16	29 4	1 4683
4	17·8	1·2504	17	30·6	1·4857
5	18·5	1 2672	18	31 9	1·5038
6	19·3	1·2856	19	33 2	1 5211
7	20·1	1·3032	20	34·6	1·5391
8	21·0	1·3222	21	36·1	1 5575
9	21·9	1·3404	22	37·6	1·5752
10	22·9	1·3598	23	39·2	1·5933
11	23·9	1·3784	24	41 0	1·6128
12	24·9	1·3962	25	42·8	1·6314
13	25·9	1·4133			

Here, too, it will be noticed that, in accordance with Schneider's observations the successive degrees or grades differ from each other according to the law of the geometric progression. In this case the equation connecting the quality and the mean fibre width may be shown to be—

$$x = 55{\cdot}88 \log_{10} F - 66{\cdot}00,$$

where F as before stands for the mean fibre width in μ and the values of x:—1, 2, 3, . . . express what Schneider calls the *finesse*.

All the four systems of finenesses which have been dealt with above differ both in the number of grades they employ and in nomenclature. Each system has been evolved from the needs of the particular country it serves, and yet all have one feature in common, viz., the scale of fineness in each country is in geometric progression. It would seem that there should be some fundamental reason for this mathematical relationship. To understand this it is necessary to remember the manner in which the wool is first graded into the different qualities. This highly skilful work is done by the sorter, who, using both eye and hand, sorts out the wool into the qualities or grades which custom has established in his particular country. The question to be answered is, why do the finenesses of these grades form a geometric progression? In 1860, Fechner,[2] in his "Elemente der Psychophysik," put forward the law now known as the Fechner-Weber Law, which states—"In order that the intensity of a sensation may increase in arithmetical progression the stimulus must increase in geometrical progression." This law, holding good between certain limits only, is expressed in his general formula, $I = C \log S$, where I stands for the sensation and S for the stimulus, and C is a constant. If we regard the wool-sorter's judgment as indicative of I, then it must immediately follow that any attempt on his part to form a gradation of finenesses will result in a scale in which successive finenesses increase in geometric progression. This, as we have shown, is exactly the case in practice in all countries.

It must, of course, not be forgotten that two senses are employed in wool sorting, viz. sight and touch, and that Fechner's Law apparently is applicable only to the former.[3] Thus the result of a selection employing the visual sense would result in a gradation of wool into classes whose mean finenesses are in geometric progression. The tactile sense may in some way be related to the auxiliary question of "handle."

The formula given by Fechner, $I = C \log S$, finds its counterpart in the different systems of classification for each country as below—

England (Wt/Length)	$x = 14{\cdot}79 \log_{10} \frac{W}{L} - 6{\cdot}58.$
France (Wt/Length)	$x = 23{\cdot}30 - 15{\cdot}77 \log_{10} \frac{W}{L}$
Germany (Fibre Width) ...	$x = 16{\cdot}15 \log_{10} F - 17{\cdot}96$
Italy (Fibre Width)	$x = 55{\cdot}88 \log_{10} F - 66{\cdot}00$

The agreement of commercial practice with the psycho-physical law of Fechner and the mathematical laws shown above may be regarded as the fundamental basis of wool sorting in all countries. This being known, a convenient and secure starting point is afforded for the discussion of an international scale of fibre fineness capable of interpretation by all countries, without in any way disturbing current trade practice.

The authors wish to record their gratitude to Mr. Henry S. Clough, J.P., for the interest he has shown in this work and for the practical suggestions he has made.

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20—THE SWELLING OF CELLULOSE AND ITS AFFINITY RELATIONS WITH AQUEOUS SOLUTIONS. PART III—THE PREFERENTIAL ABSORPTION OF SODIUM HYDROXIDE FROM DILUTE SOLUTION AS A CHARACTERISTIC PROPERTY OF CELLULOSE, AND AN INDICATION OF PREVIOUS MERCERISATION OR OTHER SWELLING TREATMENT

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CONTENTS

INTRODUCTION AND SUMMARY

Natural cotton celluloses that have been purified in the usual way by boiling with a dilute solution of sodium hydroxide, with or without further treatment with a well-controlled oxidising bleach liquor, are characterised by a more or less uniform level of reactivity or absorptive capacity. This has been proved by the work of Birtwell, Clibbens, Geake, and Ridge,[1] on the rate of oxidation with alkaline hypobromite, and by the measurements of absorption of water vapour made by Urquhart and Williams.[13] If, however, the cotton is subjected to the action of a swelling agent such as sodium hydroxide more concentrated than about $3N$, washed and dried (e.g. if it is mercerised), its reactivity is much enhanced in all the aspects characteristic of cellulose itself. This is true of the moisture absorption[13, 14], the reactivity towards alkaline hypobromite[1] or acids[11], the absorption of dyestuffs,[8] the heat of reaction with sodium hydroxide solutions below mercerising strength,[9] and the preferential absorption of sodium hydroxide from dilute solution.[15] Urquhart and Williams have shown that the relative increase of moisture absorption brought about by pre-treatment with mercerising alkali is constant at all concentrations of water vapour, or in other words treatment with alkali increases the capacity factor but not the intensity factor. As will be seen in the sequel, the capacity for absorbing alkali increases in a similar way, and the behaviour of the activated material towards water vapour or towards dilute sodium hydroxide solutions therefore resembles quantitatively that of a greater mass of the original cellulose. The ratios expressing the relative increases in activity towards the different reagents are not in general the same,

but vary from reagent to reagent. Thus for a typical technically mercerised cotton cloth the activation ratios compared with pure natural cellulose were towards water vapour 1·25, towards dilute sodium hydroxide 1·77, and towards alkaline potassium hypobromite 1·56. The evidence at present available is insufficient to warrant a discussion of the relation between these three ratios, which usually, but not invariably, place different materials in the same order of activity. Though mercerisation enhances the activity of cellulose towards the reagents mentioned above, it does not produce any of the changes usually associated with the chemical degradation of cellulose, such as loss of hair strength,[12] rise of fluidity in cuprammonium solution,[7] of copper number, or of absorption of methylene blue.[4]

The degradation of cellulose is brought about by treatment with acids or oxidising agents, and is quite distinct from that of cellulose "activation" or "mercerisation," which is caused by treatment with swelling agents. The two types of change may go on either quite independently, or, by the use of swelling agents such as sulphuric acid, may proceed together. These two quite distinct types of change are often confused in the literature, and it seems desirable to emphasise here their entire independence.

The "degradation" processes lead to the development of new chemical properties, such as reducing power, foreign to those of the purified natural cellulose, while the "activation" processes merely develop to a greater extent the original properties of the material. The most reasonable interpretation of the activation of cellulose that results from swelling is that the swelling process permanently disrupts some of the residual valence links between the hexose units, so that in the activated product there exists a greater proportion of free accessible hydroxyl groups and oxygen linkages.

Of all the enhanced properties that have been described, the preferential absorption of alkali from dilute solution seems most susceptible of easy measurement. Vieweg[15] long ago suggested that it might be employed to measure what he called "degree of mercerisation," but failed to put it forward on a basis capable of withstanding critical examination. Perhaps largely on this account the method has failed to receive the attention it merits.

The discovery that large differences exist in the amounts of heat developed[9] when different forms of cellulose react with caustic soda solutions below mercerising strength again suggested the possibility of using the reaction with such solutions for the characterisation of the state of activation of cellulose. Of the various aspects of this reaction, the determination of the preferential absorption of alkali from the change in concentration of the liquid phase is the most simple experimentally, and the present paper describes the use of this quantity as an approximate measure of the activation of the cellulose consequent upon treatment with reagents causing swelling. It is necessary to make a compromise in the choice of the reagent concentration. In certain oxidised celluloses characterised by a high absorption of the basic dyestuff methylene blue it might be expected that a small proportion of carboxylic acid groups would be present and that these would give rise to a small absorption of alkali almost independent of the concentration. Since the object of the test is to measure the reactivity of the much more weakly acid hydroxyl groups present in much larger amount, a fairly high alkali concentration must be used in order that the reaction with these latter may predominate. On the other hand the use of a solution sufficiently concentrated to swell the cellulose of itself must obviously be avoided. Experience with the reaction

has indicated half normal solution (as used originally by Vieweg) as being of a suitable concentration, for it is found that overbleaching leading to almost complete loss of strength has but little effect on the absorption of sodium hydroxide from such a solution, and that swelling of the cellulose by the reagent itself does not interfere until the concentration exceeds twice normal. The measurements now put forward indicate how the preferential absorption by various types of cellulose from solutions of sodium hydroxide up to a concentration of $5N$ varies with the concentration of the alkali. In opposition to the results of Rumbold,[10] who observes a constant absorption between N and $2N$ concentration, it is found that cotton that has been mercerised loose and air dried gives a smooth absorption curve of the characteristic "adsorption" shape, while the curve for purified natural cotton smoothly approaches an asymptote at about $2N$ concentration, rises rapidly as swelling occurs, and finally approaches a higher asymptote at $5N$ concentration. In sodium hydroxide solutions of any chosen concentration below $2N$, the absorptions characteristic of various samples of cellulose bear a constant ratio to each other.

In the present paper the preferential absorption of alkali, calculated from the change in concentration of the liquid phase on the assumption of a constant mass of water therein, is put forward as a characteristic property of cellulose. In the first paper of this series, however, it was pointed out that this quantity probably has little fundamental significance and is to be regarded as dependent, not only on the amount of sodium in chemical combination with the cellulose, but also to a smaller extent on the amount of water imbibed by the cellulose phase. This latter quantity is not as a rule exactly known, but rough values may be obtained from the data of Coward and Spencer,[6] and by means of these the combined sodium may be calculated from the observed preferential absorption.*

If this be done it is found that the preferential absorption is less than the combined sodium in a ratio varying between 0·65 and 0·75 according to the possible variations of alkali concentration between $N/10$ and $5N$, and of water imbibition between 4 and 16 moles per mole. Over such an extreme range this variation in ratio may be regarded as small enough to justify the use of the preferential absorption as an approximate measure of the reactivity of celluloses towards alkali.

In reagents such as caustic soda, zinc chloride, or sulphuric acid of suitable concentration and temperature, cotton cellulose may swell to a great extent. If the swelling, as judged by change of dimensions, is about equal to or more intense than that afforded by mercerising caustic soda at the ordinary temperature, the washed and dried product absorbs nearly three times as much alkali as does the unswollen material. Solutions of cuprammonium hydroxide just below solvent concentration are, however, capable of causing great swelling without a corresponding large increase in the activity of the product towards alkali. The rayons, representing cellulose that has passed through

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*The relation is readily obtained from the equations of the first paper and is—

$$p = \frac{a}{2} + \sqrt{\frac{a^2}{4} + c^2W^2} - c(W - a)$$

where p = preferential absorption, moles per mole.
a = molar fraction of cellulose existing as sodium salt.
c = alkali concentration in external phase, moles per mole o H_2O.
W = moles of water imbibed by one mole of cellulose.
It will be noted that as c approaches zero, p approximates to a.

a phase of complete dissolution, absorb more alkali than any samples of cellulose that have merely been swollen.

The application of tension to yarn or cloth restrains the swelling of the hairs, and leads to a product of lower reactivity towards alkali. Drying at a high temperature also reduces the alkali absorbing power of certain mercerised cottons of high activity. Cotton mercerised in the grey state and then scoured by boiling with a dilute solution of caustic soda shows a lower alkali absorption and a lower reactivity towards alkaline hypobromite[1] than cotton mercerised in the scoured condition. Measurement of its capacity for absorbing dilute alkali has been used to investigate the reactivity of cotton that has been treated with caustic soda solutions of varying concentration. With caustic soda of concentrations above 15% the product has a fairly uniform level of activity, but the results show that more than three minutes' immersion in the mercerising alkali is required to attain the maximum effect with solutions more concentrated than 40 per cent. When solutions of caustic soda of higher concentration than 25% are used for mercerising, a less active product is obtained if the alkali is washed off by a solution of brine, than when water only is used for washing. It is to be presumed that the use of brine prevents the transient swelling that takes place when cellulose in equilibrium with concentrated alkali is suddenly immersed in water. This effect has been described in a previous paper.[9]

The determination of the amount of alkali absorbed by mercerised cotton prepared with an extremely slow washing process has been used to show that mercerisation does not consist essentially in the development of an imperfectly crystalline arrangement due to rapid coagulation of cellulose from a state of semi-solution.

A method for the routine examination of samples of cotton goods that have passed through the industrial process of mercerisation could be based on the determination of the capacity of the material for absorbing sodium hydroxide. It has, however, been found that similar information as to the state of the cellulose is afforded in a manner less exacting experimentally by the determination of the preferential absorption of barium hydroxide from a quarter normal solution. The technique of this test, and some of the results obtained with it, are described in the following paper, but for comparison the baryta absorption ratios of some of the cotton samples are given along with the soda absorption ratios in the present paper.

EXPERIMENTAL METHOD

(a) Standard Solutions

Decinormal hydrochloric acid is prepared by weight dilution of the constant-boiling acid, and is regarded as the standard. Half-normal sodium hydroxide is prepared by weight dilution of a filtered saturated solution of the pure reagent. The titre of 10 c.c. of the half-normal alkali against the decinormal acid is determined within 0·02 c.c., methyl red being used as indicator, and will be called the initial titre. As the end point is approached the solution is boiled to remove carbon dioxide and cooled, until the permanence of the colour indicates that the pH is stable at about 5·0.

(b) Determination of the Absorption

The moisture present in cotton materials affects the apparent absorption of alkali in two opposite ways, first by diluting the alkali solution and so

increasing the apparent absorption, and secondly decreasing it on account of the fact that the amount of cellulose actually present is less than that assumed. With industrially mercerised cottons it so happens that these opposite effects almost balance, and in general a satisfactory allowance is made if the moisture regain of unmercerised cottons is taken to be 6%, of mercerised cottons 9%, and of regenerated celluloses 12 per cent. Thirty c.c. of the $N/2$ alkali are added to a weight of the sample corresponding to 2 g. of dry cellulose, and the whole is shaken, or allowed to stand with occasional shaking, for not less than two hours, preferably in a thermostat at a fixed temperature. Ten c.c. of the clear solution are then titrated with the decinormal acid, with the aid of the same carefully calibrated pipette and burette as were used in obtaining the initial titre. Occasionally with very much overbleached samples it may be necessary to filter the alkali through a coarse sintered glass filter to remove fragments of cotton hairs.

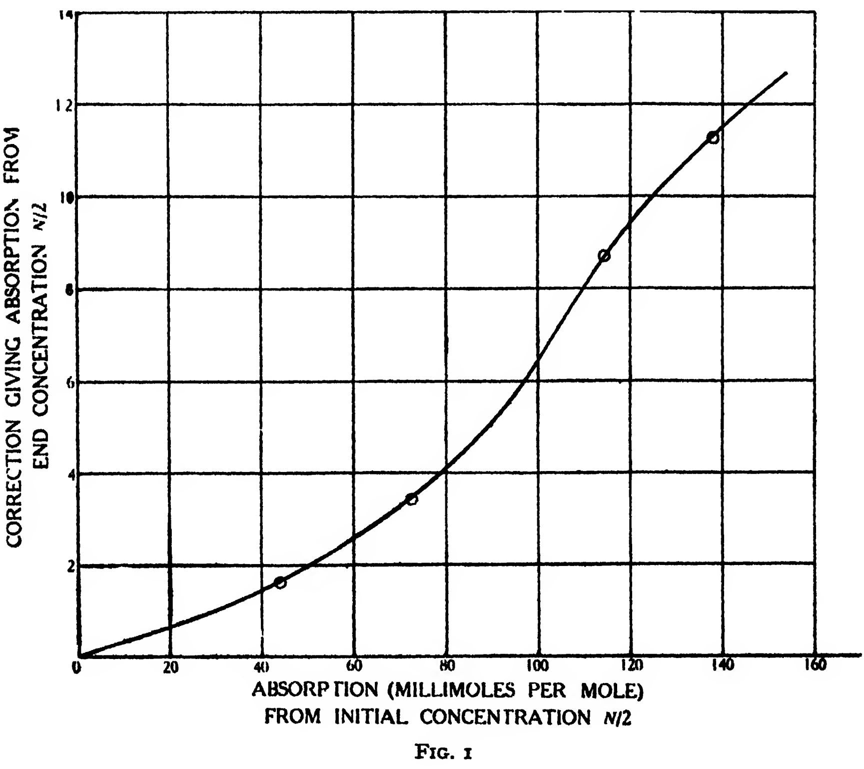

FIG. 1

(c) Calculation of Results

To determine the difference in the titre of the alkali due to absorption by the cellulose, the initial titre must be corrected for the dilution by the estimated water content of the sample, and, if thermostat control is employed so that the pipetted equilibrium solution is at a higher or a lower temperature

than the decinormal acid, then the obvious small correction for change of volume should be made to the final titre. If the difference between the corrected initial and final titres is x c.c. of decinormal acid, then the preferential absorption calculated on the basis of a constant liquid phase volume* is $\frac{x}{10} \times \frac{30}{10} \times \frac{162}{2}$ milli-equivalents of alkali per $C_6H_{10}O_5$ equivalent. This figure refers to a constant initial soda concentration, the final equilibrium concentration of course being lower as the amount of absorption increases. The absorption calculated as above can be corrected to that obtained when the end concentration is half-normal, if the effect of concentration on the absorption is known. This effect was determined in a series of experiments to be described later, and a curve has been constructed (Fig. 1)† giving the correction to be applied in order to obtain the absorption from a solution of end concentration half-normal, when the standard weight of sample and volume of half-normal solution have been used.

It has been found convenient for the purpose of comparing samples of cellulose to divide this corrected figure by the mean absorption characteristic of natural cotton cellulose that has been boiled with dilute alkali to remove impurities, and the resulting ratio will be called the "soda absorption ratio."

EXPERIMENTAL RESULTS

(1) Effect of Time

Sixteen grams of the sample were shaken with 240 c.c. of the half-normal alkali, and 10 c.c. portions were withdrawn from time to time for analysis. The results given in Table I show that absorption is virtually complete after two hours.

Table I

Observed Absorption (Milli-equivalents per Mole) from $N/2$ solution. Temperature 17° to 20° C.

Time (hours)	½	¾	1	2	3	6	24	48	72
Scoured Sakel yarn ...	44·6	...	44·9	...	...	...	45·1	45·1	...
Trade mercerised poplin ...	71·3	71·7	73·0	74·5	...	75·3	74·8	...	...
Brysilka bleached rayon ...	147·2	...	147·3	...	147·3	146·2	146·4	...	144·7

(2) Effect of Temperature

The standard procedure was followed, but the absorption bottles were kept in thermostats during the whole of the determination. It may be concluded from the results given in Table II that slight fluctuations of room temperature are not likely to affect the absorption seriously, but that a thermostat should be used to define exact values.

* Though any definition of preferential absorption is quite arbitrary, the quantity calculated as if no solvent were absorbed is the most simple. Fortunately the volume of a sodium hydroxide solution is, up to quite high concentrations, nearly the same as that of the contained solvent, i.e. the apparent volume of the solute is sensibly zero.

Per cent. NaOH (g. per 100 g. solution)	0	2	4	10	16
Wt. of water in 1,000 c.c. of solution at 18° C.	998·6	1000·9	1001·8	998·8	988·1

On this account the preferential absorption calculated as above on the basis of constant volume of solution is almost identical with that obtained on the basis of constant mass of solvent in the liquid phase.

† Fig. 1 may be accurately reconstructed on squared paper from the following data, which apply only when the dry weight of the sample is two grams, and the volume of solution 30 c.c.

Observed Absorption at initial concentration $N/2$	0	44·0	72·5	114·5	138·0
Correction to end concentration $N/2$	0	+1·6	+3·4	+8·7	+11·3

Table II
Absorption of NaOH from $N/2$ Solution

Sample	Milli-equivalents per mole at				
	0° C.	5° C.	20° C.	25° C.	35° C
Scoured Sakel yarn	...	57·2	44·9	42·5	38·8
	...	57·2	44·5	42·5	38·6
Above yarn treated loose with 25% NaOH, washed, air dried	129·0	...	106·4	...	93·4
	130·2	...	106·1	...	93·4

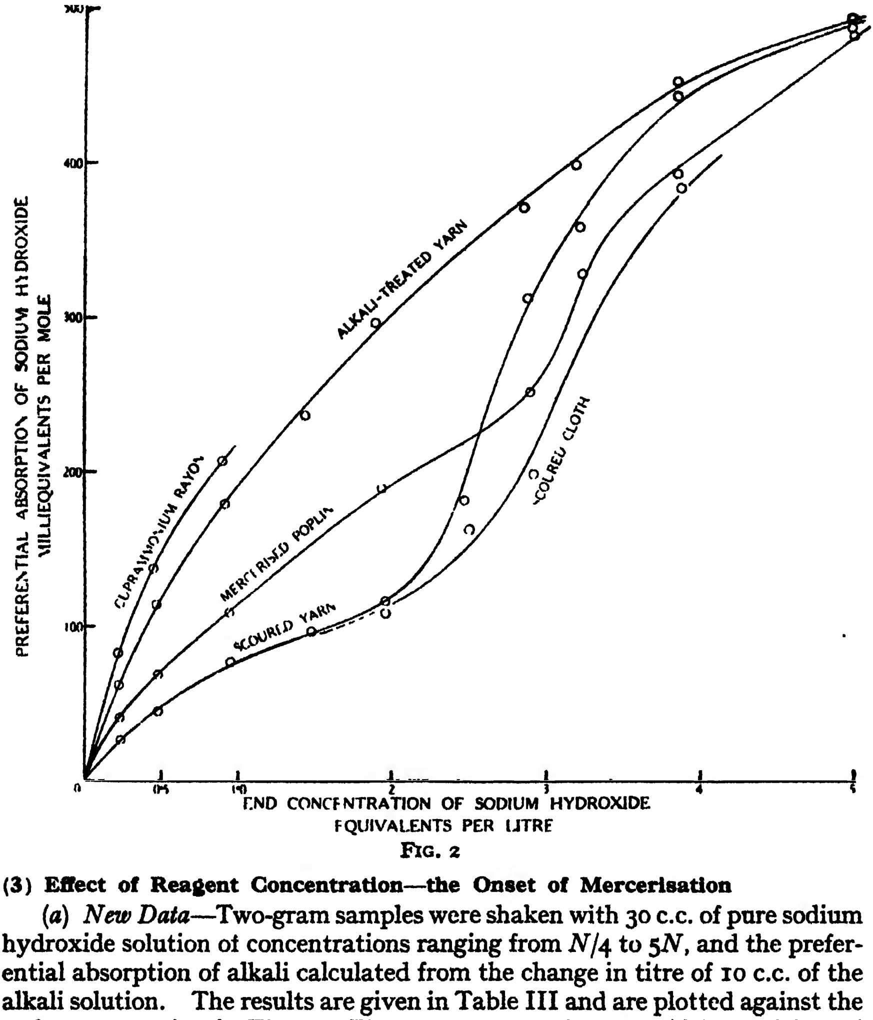

Fig. 2

(3) Effect of Reagent Concentration—the Onset of Mercerisation

(*a*) *New Data*—Two-gram samples were shaken with 30 c.c. of pure sodium hydroxide solution of concentrations ranging from $N/4$ to $5N$, and the preferential absorption of alkali calculated from the change in titre of 10 c.c. of the alkali solution. The results are given in Table III and are plotted against the end concentration in Fig. 2. The curves are such as would be anticipated from the hypothesis put forward in the first paper of this series. Their shape up to a certain critical concentration, or for the alkali treated yarn over the whole range, is typical of a chemical change in a homogeneous system approaching completion as the reactant concentration rises. This is probably to be interpreted as the reaction of the accessible hydroxyl groups with alkali proceeding approximately in accordance with the Law of Mass Action. Beyond the critical concentrations the absorption curves of unmercerised and of technically mercerised cotton rise more steeply, and finally flatten out towards an asymptote which is much the same for all the samples investigated.

This behaviour probably indicates a rapid increase up to the same maximum, in the number of accessible hydroxyl groups as the reagent swells the cotton, and is better illustrated by the presentation in Fig. 3. Here the absorption values of the samples are expressed relative to the absorption of the alkali treated yarn at the same end concentration, since the absorption curve of this latter shows no inflexion indicative of the activating effect of swelling. The absence of any such inflexion in Fig. 2 makes it probable that this activating effect persists more or less undiminished when the swollen material is washed and dried at a low temperature.

Fig. 3 shows that the amounts of alkali preferentially absorbed by the cotton samples maintain the same ratios to each other in sodium hydroxide solutions up to twice normal. This indicates that the absorption of alkali is giving a measure of the relative amounts of acidity which the samples possess, and that the acidity varies from sample to sample in capacity but not in intensity.

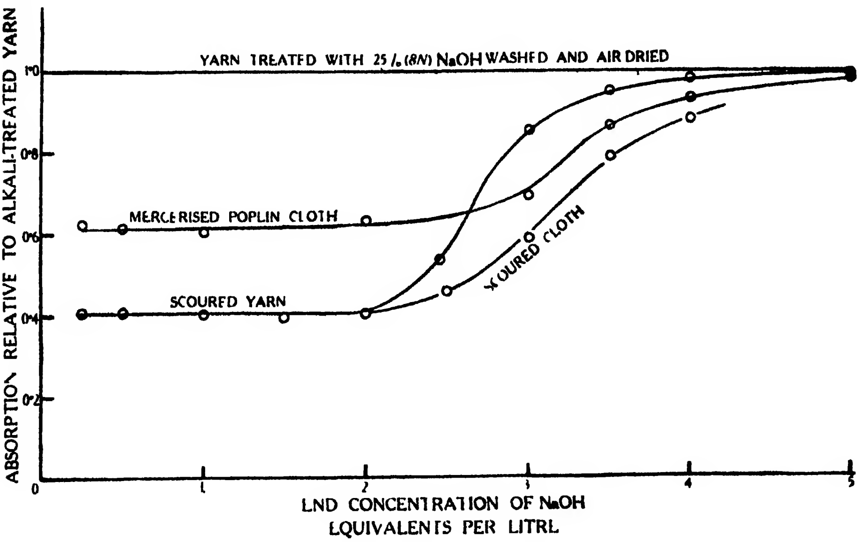

Fig. 3

The scoured yarn shows a rapid rise in absorbing power between 2 and $3N$, the poplin cloths both mercerised and unmercerised between 3 and $4N$, so that all four samples exhibit much the same absorption from the $5N$ alkali. It appears that this activation is largely conditioned by mechanical factors that may restrain the dimensional swelling of the cotton cellulose, for the rise in absorption occurs at an appreciably higher alkali concentration for the cloths than for the yarns. The work of Calvert[2] has shown that the shrinkage of single cotton hairs in sodium hydroxide solutions is sensitive to very small applied loads, and that under load the maximum shrinkage occurs at a higher concentration of alkali. There is, of course, a close correlation between the contraction in the length of the hairs, and their increase in volume in caustic soda solutions,[5] and it is now suggested that the extent of this swelling largely determines the reactivity towards alkali of the washed and dried product.

Fig. 3 shows that for the purpose of discriminating between samples of cotton cellulose, the choice of reagent strength may lie anywhere below twice

normal; the standard half-normal reagent is therefore unobjectionable from the point of view of any possible swelling action on natural celluloses.

(*b*) *Results of other Workers*—The amount of alkali preferentially absorbed by cotton cellulose from sodium hydroxide solutions of different concentrations has been determined by several workers in the past, and a critical summary of their results is given by Clibbens.[8] These earlier workers have been concerned with proving or disproving the existence of a constant absorption from solutions of between 16% and 24% sodium hydroxide, and their results have little pretension to accuracy in the region of more dilute

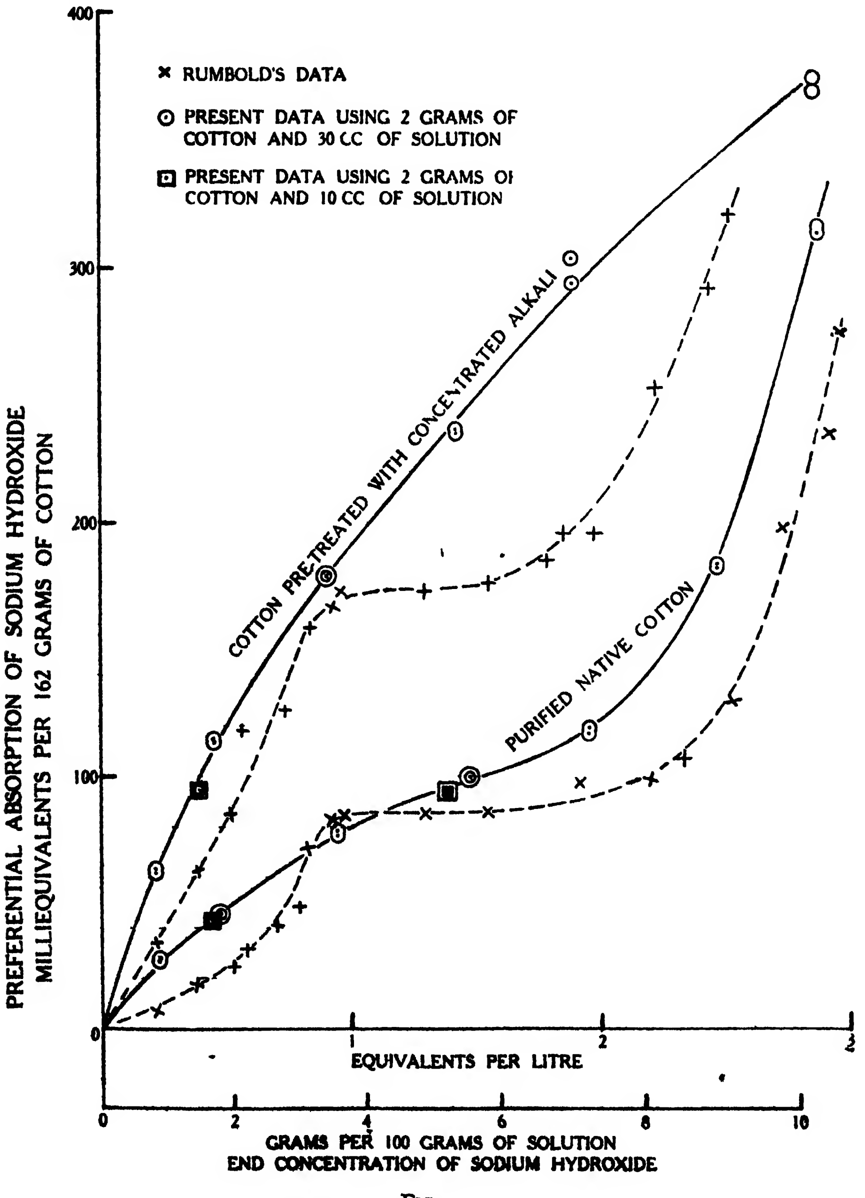

Fig. 4

solutions with which the present paper is chiefly concerned. Quite recently, however, a paper has been published by Rumbold,[10] describing measurements of the preferential absorption of sodium hydroxide by cotton over the concentration range 0 to 10 per cent. His results are entirely at variance with those now put forward, for he finds for both native cotton (of uncertain treatment) and for the same pre-treated with 20% caustic soda solution, amounts of absorption that remain constant from solutions containing between 4 and 8 g. of sodium hydroxide per 100 g. of solution. If his data are converted into the units used in the present paper it is found that when the end concentration is approximately normal there is fair agreement with the values now given in Table III (Fig. 2), but that serious discrepancies exist at higher and at lower concentrations. Fig. 4 gives the two sets of results on the same basis. No useful discussion of this discrepancy is possible, but attention may be drawn to the following points—

(1) Rumbold's ratio of 0·4 g. of cotton to 50 or 60 c.c. of solution is one-tenth of that employed in the present work, so that his value for the absorption from 2% solution would be subject to a 50% error if there were an error of half a milligram in each of the two weights of a sodium chloride residue on which the measurement depends.

Table III

Effect of Reagent Concentration on the Preferential Absorption of Sodium Hydroxide by Various Celluloses

(The duplicate experimental figures are given for the scoured and the alkali treated yarn, on account of the discrepancy between these results and those of Rumbold.[10] The remaining values are the means of duplicates usually agreeing within 1 or 2 per cent.)

Sakel Yarn scoured with 1% Caustic Soda at 20 lb. excess pressure for 6 hours.

(Temperature of experiment between 17° and 20° C.)

Initial concentration, equivalents per litre	0·2475	0·5007	0·981·	1 516	2·002	2·54
End concentration, equivalents per litre	0·234	0·479	0·948	1·468	1·95	2·46
Absorption, milli-equivalents per mole	26·7	45·0	78·1	98·9	117·0	182·3
	27·4	45·0	76·5	99·9	119·0	183·5
Initial concentration, equivalents per litre	2·992	3·35	4·00	5·17	(to nearest 3 figures)	
End concentration, equivalents per litre	2·86	3·20	3·81	4·97		
Absorption, milli-equivalents per mole	313·	357·	444·	486·		
	316·	362·	447·	493·		

Poplin Cloth 143/78, 50/50 *Egyptian, scoured as above.*

Initial concentration, equivalents per litre	0·496	2·002	2·557	2·992	4·00
End concentration, equivalents per litre ...	0·478	1·95	2·49	2·91	3·85
Absorption, milli-equivalents per mole ...	45·4	108·	164·	200·	385·

Poplin Cloth technically bleached and mercerised.

Initial concentration, equivalents per litre ...	0·2475	0·5007	0·981	2·002
End concentration, equivalents per litre	0·230	0·465	0·934	1·92
Absorption, milli-equivalents per mole	40·6	71·5	109·8	191·
Initial concentration, equivalents per litre ...	2·992	3·35	4·00	5·17
End concentration, equivalents per litre	2·88	3·21	3·83	4·97
Absorption, milli-equivalents per mole	253·	330·	394·	484·

Sakel Yarn scoured as above, treated with 25% Caustic Soda solution for 30 mins. at 25° C., washed, soured, washed, and dried in air at 18° C.

Initial concentration, equivalents per litre	0·2475	0·5007	0·981	1·516	2·002
End concentration, equivalents per litre ...	0·221	0·452	0·905	1·410	1·88
Absorption, milli-equivalents per mole	61·8	113·2	178·5	235·5	304·
	63·1	114·5	179·0	236·4	292·
Initial concentration, equivalents per litre	2·992	3·35	4·00	5·17	
End concentration, equivalents per litre ...	2·84	3·18	3·81	4·96	
Absorption, milli-equivalents per mole	374·	396·	454·	501·	
	369·	401·	454·	496·	

Table III—*continued*

150 Denier bleached filament cuprammonium rayon.

Initial concentration, equivalents per litre ...	0·2475	0·5007	0·981
End concentration, equivalents per litre	0·212	0·440	0·888
Absorption, milli-equivalents per mole	82·8	137·	207·

(2) The present paper is almost wholly based on the absorption from half-normal or 2% solution; a routine test of mercerised cottons based on this measurement has been in use for some time, and the standard value for scoured natural cotton, which is roughly double that obtained by Rumbold, is repeated within 2% by different workers using different solutions and apparatus.

(3) Experiments in which 2 g. of cotton were used with only 10 c.c. of solution, whereby the concentration fell by about 11% of its own value, instead of by less than 1% as in Rumbold's experiment, gave results falling on the smooth curve (see Fig. 4) obtained with the standard ratio of cotton to solution. With the abnormally high ratio of cotton to solution, equilibrium was reached only after standing for at least 24 hours.

(4) The Soda Absorption Characteristic of Cottons of Different Growths

A number of yarns were spun to 2/50's from different varieties of cotton, scoured together in 1% caustic soda for six hours at 20 lb. excess pressure, soured and washed in the usual manner until perfectly neutral. The samples were then air dried and were found to absorb the following amounts of caustic soda, corrected to end concentration $N/2$ (Table IV).

Table IV
(Temperature 18° to 20° C.)

Variety of Cotton	Hair Weight per cm mgms × 10^5	Soda Absorption: Milli-equivalents per mole	Soda Absorption: Ratio
Arizona (immature)	107	47·4	1·02
Egyptian Sakellaridis ...	149	44·0	0·95
Brazilian	164	45·4	0·97
Egyptian Uppers	196	44·0	0 95
Peruvian Mitafifi	202	50·0	1·08
Tanguis	212	46·5	1·01
Mean absorption		46·2	

The various samples of scoured and bleached sliver, yarns, and fabrics that have been encountered have all given values of the soda absorption lying between 45 and 48 milliequivalents per 162 g. of dry cotton. A sample of scoured ramie fibre gave an absorption of 46·8.

This approximate constancy in the soda absorption characteristic of purified natural cellulose is the basis of the procedure adopted in Table IV and followed in the sequel, whereby the absorption characteristics of a sample under the standard conditions and corrected to $N/2$ end concentration is divided by the mean absorption of Table IV to obtain the "soda absorption ratio."

If the absorption proceeds in a thermostat at 25° C., the divisor used in obtaining the ratio is 42·5 (see Table II). The ratio itself is practically independent of temperature.

The determination of soda absorption is valueless with raw cotton, since constituents other than cellulose interfere, giving an abnormally high absorption and a bad end point in the titration. On the other hand, the severity of the scouring treatment has no appreciable effect on the soda absorption ratio

of the product, which for a variety of trade samples of bleached yarn and cloth, for a sliver scoured with 2% caustic soda at 40 lb. excess pressure for ten hours, and for a yarn after open boiling or high pressure boiling with caustic soda, has always fallen within the limits 0·95 to 1·02.

(5) Effect of Previous Chemical Modification of the Cellulose by Acid Hydrolysis or by Oxidation

It is to be anticipated that the reactivity of cellulose towards alkali will be affected by chemical modification, particularly that of the type occurring in alkaline oxidising solutions, and leading to a high absorption of the basic dyestuff methylene blue. On the other hand, if more than quite a small stoichiometric fraction of cellulose is chemically attacked, the fibrous structure is lost, so that interest is restricted to samples in which the proportion of hydroxyl groups is overwhelmingly great. By avoiding the use of very dilute alkali, which would enhance the relative effect of groups more acid than the very weakly acid hydroxyl, it therefore seemed possible that an absorption sensibly independent of previous acid or oxidising attack might be obtained. This conjecture is borne out by the data presented in Table V.

Table V

Treatment of Sample		Soda absorption ratio	Copper Number	Absorption of Methylene Blue	Approx. loss of Hair Strength %
HCl 200 g. per litre at 20° C.	4 hours	0·97	0·85	...	42
	24 hours	0·97	2·44	...	70
Alkaline hypobromite		0·99	...	1·27 from water	
		1·06	...	8·1 at pH7	almost complete

(6) Effect of Treating a Sample of Cotton with Acid or Alkali immediately before Washing

It is known that cotton cellulose may retain traces of acid or alkali, which are resistant to washing with water, but the data of Table VI show that the soda absorption of a sample has the same value whether it has been treated with dilute caustic soda or with dilute hydrochloric acid before the final washing process.

Table VI

Sample	Soda Absorption Ratio		
Scoured Sakel yarn treated loose with 20% Caustic Soda solution—			
Washed with water till neutral, air dried		2·54	
Soured with $N/5$ HCl, washed, air dried		2·53	
Three technically mercerised cloths –	A	B	C
Treated $N/2$ NaOH, washed, and air dried	1·74	1·61	1·71
Treated $N/5$ HCl, washed, and air dried	1·70	1·60	1·70

(7) The Absorptive Capacity of Cotton that has been Swollen in Caustic Soda Solutions of Different Concentrations

Hanks of scoured twofold 40's Sakel yarn were immersed in a loose condition in caustic soda solutions maintained at 25° C., washed, soured for half an hour in $N/5$ hydrochloric acid, washed for several days till the pH of the wash water was constant, and dried on sticks at the laboratory temperature. Three series of samples were prepared, differing in time of treatment and in method of washing off the caustic soda, as follows—

(1) To obtain the effect corresponding to the equilibrium swelling in each solution the yarn was immersed for 24 hours, air being excluded by evacuating the vessel and filling with nitrogen, and to avoid any effect due to transient swelling the samples were in the first instance washed in saturated brine.

(2) To determine the effect due to such transient swelling samples were immersed as above for 24 hours, and washed in the first instance by plunging into a large excess of cold water.

(3) To obtain samples comparable in properties with those prepared by Urquhart and Williams,[12,14] for the estimation of moisture absorption, hanks were immersed for three minutes and washed with cold water.

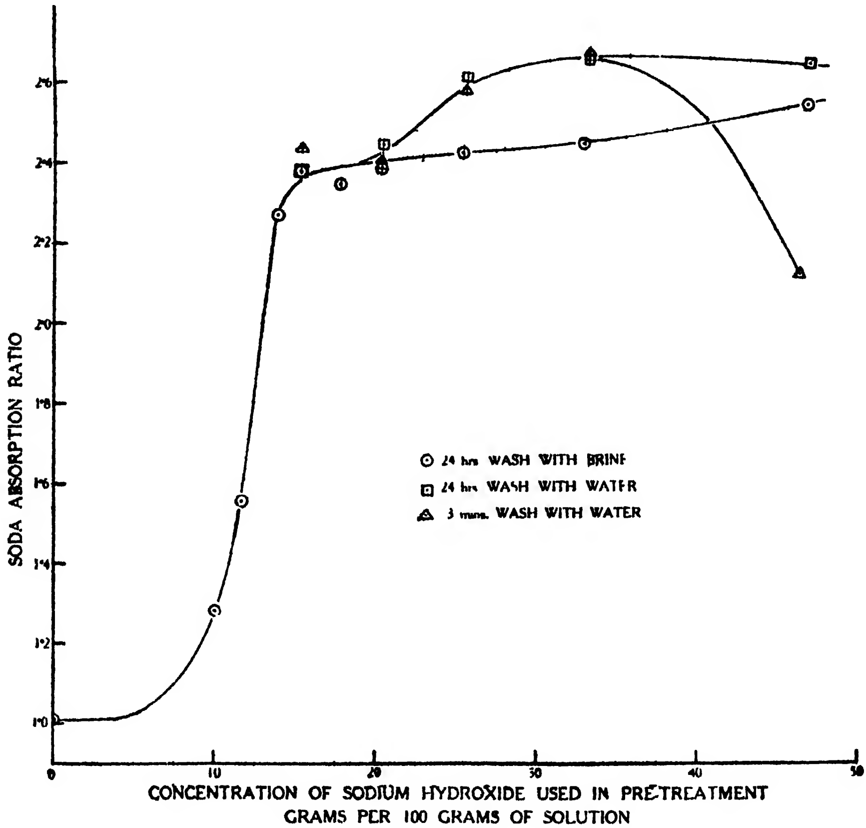

FIG. 5

The washed air-dried samples were used for the determination of soda absorption ratio in the standard manner and the results are given in Table VII (Fig. 5). Three conclusions are at once apparent. The effect of the treatment with sodium hydroxide solution increases very rapidly as the concentration is increased from 10 to 14%—this is also true of the moisture absorption[12,14] and reactivity towards alkaline hypobromite[1] of alkali-treated cotton. At the highest concentration of alkali three minutes' immersion is not adequate to produce the maximum effect—it has already been pointed out[9] that sodium hydroxide solutions approaching saturation swell cellulose relatively slowly. At all concentrations above 20% a slightly more reactive product is obtained by washing with water than by washing with brine. This effect is attributed to enhanced but transient swelling of the cellulose induced on account of the momentary disturbance of osmotic equilibrium between the external solution and the cellulose gel.[9]

It is of interest to compare the absorptive capacity of the product with the extent to which the cotton cellulose was swollen in the pretreating solutions. The amount of swelling is known for regenerated sheet cellulose and sodium hydroxide solutions at 25° C.,[9] and a fair estimate of the amount of swelling of the Sakel cotton in yarn form is afforded by the ultimate shrinkage in the alkali solutions of lengths of this yarn, under tautening load of 0·3 g. In Fig. 6 both these quantities are compared with the soda absorption ratio of yarn that has been treated for 24 hours with alkali solution of the indicated concentration, and washed in the first place with brine It will be seen that that whilst the soda absorption of the product reflects the rapid increase in swelling power that occurs between 10 and 14% sodium hydroxide, it is substantially unaffected by the fall in swelling that follows as the concentration approaches 30 per cent.

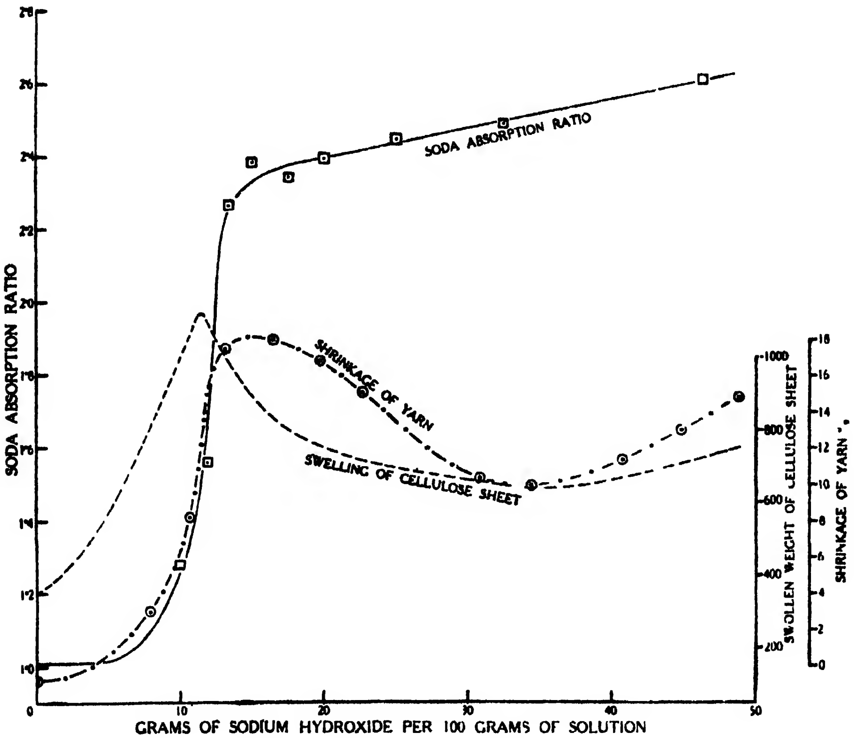

Fig 6

The inference that the soda absorption ratio does not reflect all magnitudes of the previous swelling of the cellulose is supported by an observation made on scoured yarn treated with 11% (3·1*N*) caustic soda solution at − 10° C. In spite of the obviously much greater swelling that occurs at this temperature[1] the soda absorption ratio of the product was only 2·67—no higher than that attainable by treatment at 25° C.

Curve A of Fig. 7 represents the soda absorption ratios from the standar(half-normal reagent (relative to scoured cotton as unity) of cotton yarn pretreated with sodium hydroxide solutions of the concentrations shown o1 the scale of abscissæ. The curve runs horizontally at 1·0 for some time, anc then rises fairly steeply between 10 and 14% sodium hydroxide up to ar

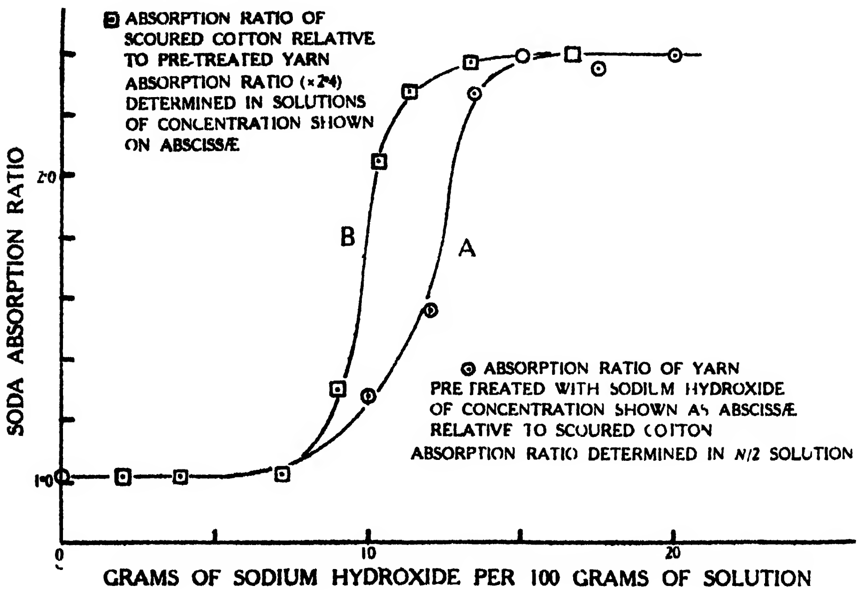

FIG 7

Table VII

Soda Absorption Ratios of Scoured 2/40's Sakel Yarn which has been Treated Loose with Sodium Hydroxide Solution at 25° C., Washed, Soured, Washed and Air-dried

Concentration of Caustic Soda for pretreatment, g per 100 g solution	Soda Absorption Ratios (duplicate measurements)						
	In Alkali Solution 24 hours, first washed with—				In Alkali 3 mins., water washed		
	Saturated brine		Cold water				
10	1·28	1·27	...	...	...	...	...
12	1·55	1·57	...	..	...	...	...
13·4	2·28	2·26	...	...	...	...	...
15	2·38	2·39	2·38	2·38	2·45	2·45	2·45
17·5	2·33	2·36	...	...	...	...	...
20	2·40	2·40	2·44	2·47	2·42	2·41	...
25	2·44	2·46	2·66	2·62	2·60	2·61	...
32·4	2·49	2·49	2·68	2·72	2·73	2·71	...
46·2	2·61	2·62	2·72	2·72	2·19	2·19	...

absorption ratio of 2·4. The other curve (B in Fig. 7) has been constructed from the data of Fig. 2. It represents the results of absorption measurements actually made in solutions of the concentration shown, expressed as the absorption characteristic of scoured cotton relative to that characteristic of the alkali-treated yarn of Fig. 2. To facilitate comparison the absorption of the latter sample is regarded as 2·4 units from any solution. Thus in Fig. 7 are shown two curves on a similar basis, one (B) representing the increase of reactivity that cotton yarn displays when immersed in sodium hydroxide solutions of various concentrations, the other (A) showing the amount of such activation that persists after the sample has been removed from the alkali, washed, and air dried. From the fact that the curves coincide at the starting point and above 15% sodium hydroxide, it may be concluded that the increase of activity caused by solutions of concentration greater than 15% is not in any way diminished by washing the alkali off and drying the sample at a low temperature. On the other hand, the divergence of the curves between 10 and 14% sodium hydroxide indicates that the activation that occurs in these solutions is not wholly permanent.

(8) Effect of Restrained Shrinkage and of Temperature of Drying on the Absorptive Capacity of Grey and Scoured Yarns Treated with 25% Sodium Hydroxide Solution

Hanks of twofold 50's Sakel yarn, both natural grey and scoured with 1% caustic soda at 20 lb. excess pressure for six hours, were reeled to 54 inches girth, and the grey hanks thoroughly wetted by boiling for a few minutes with a 1% solution of Turkey Red oil. The samples were treated for five minutes with 25% sodium hydroxide solution at the ordinary temperature on a hank mercerising machine, washed with hot water, soured in fifth-normal hydrochloric acid for half an hour, washed till neutral, and dried either in an oven at 110° C for six hours or in the laboratory air. The soda absorption ratios of the dried samples were determined in the standard manner and are given in Table VIII along with baryta absorption ratios determined as described in the following paper.

Table VIII

Alkali Absorption Ratios of Yarn Mercerised with 25% Caustic Soda

		Dried at room temperature		Dried at 110° C for 6 hours	
		Na ratio	Ba ratio	Na ratio	Ba ratio
Scoured and then mercerised	Loose (about 15% shrinkage)	2·55	2·70	2·27	2·52
	Loose and restretched ...	2·07	2·10	1·93	1·98
	No shrinkage allowed ...	1·96	2·05	1·89	1·99
	Cloth mercerised loose ...	2·13	...	...	...
Mercerised in the grey state and then scoured	Loose (about 15% shrinkage)	2·09	2·20	1·84	1·97
	Loose and restretched ...	1·76	1·79	1·76	1·83
	No shrinkage allowed ...	1·68	1·73	1·69	1·75

(The samples mercerised loose were washed with cold water initially, the rest with hot water.)

"Loose and restretched" signifies that the yarn was allowed to shrink freely during the first four minutes and was extended to its original length during the last minute before washing, whilst the sample treated "loose" was at no time under any external restraint. The samples mercerised grey were scoured before the determination of soda absorption.

The most remarkable feature of these results is the great decrease in activity caused by mechanical restraint or even restretching during the treatment with alkali. This seems to indicate that the dimensional swelling of the cellulose rather than the chemical reaction with sodium hydroxide determines the alkali absorbing power of the product.

There is a noteworthy difference between the yarns mercerised in the grey and in the scoured states. It is also evident from Table VIII that drying at 110° C. decreases the reactivity of the most absorptive samples, but has no effect on the less reactive samples mercerised in the grey state with restrained shrinkage.

(9) The Mercerisation of Cottons of Different Origins

The yarns whose absorption ratios in the scoured state were given in Table IV were treated together in the grey state with 24% caustic soda solution, 4% contraction in length being allowed, restretched to grey length, washed, scoured, washed, and air dried. The soda absorption ratios of the products and of the scoured unmercerised yarns are given below—

	Sakel	Egyptian Uppers	Brazilian	Tanguis	Arizona	Peruvian
Scoured only ...	0·95	0·95	0·97	1·01	1·02	1·08
Mercerised ...	1·57	1·57	1·62	1·63	1·63	1·68

There is a general tendency for high absorption after mercerisation to correlate with high absorption in the unmercerised state, but the differences between the various cottons are relatively small and the increase due to mercerisation is approximately constant.

(10) Extremely Slow Removal of Alkali

Cotton cellulose swollen in alkali of mercerising strength is in a highly distended state which may be regarded as bordering upon one of complete dissolution. When the alkali is washed out by means of an excess of water the cellulose gel shrinks and presumably the mutual attractions of the polar hydroxyl groups become operative again. When the process was regarded from this point of view it seemed possible that the activation of cellulose that results from "mercerisation" might be due to a rapid coagulation of cellulose from a state of semi-solution, leading to a more imperfect crystalline arrangement, in which the mutual affinities of the hydroxyl groups were less condensed. On this hypothesis it might be expected that extremely slow removal of the alkali might give time for a reversion to the original condensed, more perfectly crystalline state. To test this possibility scoured Sakel yarn was immersed in 21% caustic soda solution both loose and on a frame permitting no shrinkage, and the solution was diluted by running in water at a very slow but steadily increasing rate. After two weeks' steady dilution the solution still contained 10% of caustic soda. The products were finally washed freely, soured and washed in the usual way, and air dried. Their soda absorption

ratios, along with those corresponding to a normal rapid wash after 30 minutes' immersion in the alkali are given in Table IX.

Table IX

Soda Absorption Ratios of Scoured Sakel Yarn Treated with 21% NaOH, Washed, and Dried

		Air-dried	Dried 48 hours at 110° C.
Extremely slow wash	Loose	2·52	2·17
	No shrinkage allowed	2·12	1·88
Normal wash ...	Loose	2·52	2·13
	No shrinkage allowed	1·95	1·66

The results do not confirm the supposition, nor does any latent difference between the slowly and rapidly washed products develop on drying at a high temperature. The prolonged treatment, however, seems to have led to a gradual decrease of stress in the sample treated on the frame with consequent greater swelling and greater reactivity of the product.

(11) The Effect of Pretreating Cotton with Swelling Agents other than Alkalis

The increase in capacity for absorbing sodium hydroxide is brought about not only by pretreatment with alkalis in concentrated solution, but also by the action in suitable concentration of reagents such as sulphuric acid, zinc chloride, and cuprammonium hydroxide, which appear to have little in common except the power of swelling cellulose. The fragmentary data given in Table X serve to show the existence of this effect. The baryta absorption ratios included in the table will be discussed in the following paper.

Table X

Pretreating solution		Estimated extent of swelling	Soda Absorption Ratio	Baryta Absorption Ratio
Sulphuric acid, 65%, for 30 secs at 20° C ...	Loose ..	Very great, loose yarn approaching complete dissolution	3·20	3·20
	No shrinkage		2·55	2·52
Zinc chloride, 73·3%, for 24 hours at 25° C	Loose ...		3·15	3·33
	No shrinkage		2·48	2·36
Cuprammonium hydroxide— Cu 5·5 g. per litre, NH_3 88 g. per litre 1 hour at 20° C	Loose ...		1·45	1 36
Cuprammonium hydroxide— Cu 5·0 g. per litre, NH_3 80 g. per litre 1 hour at 20° C	Loose ..	Greater than in 25% NaOH	1·03	1·02
Caustic soda, 25%, at 25° C	Loose ..	...	2·55	2·60
The untreated 2/40's scoured Sakel yarn		..	1·01	1·01

As far as may be judged from visual observation, great swelling in the reagent seems to bring about high activity of the product, but cuprammonium hydroxide is an exception, for very great swelling in this reagent yields a product of comparatively low activity.

The experimental work was done by Messrs. T. Brownsett, L. Hanna, and R. Waite.

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21—A CONTRIBUTION TO THE THEORY OF MILLING

PART I—A METHOD FOR MEASURING THE SCALINESS OF WOOL FIBRES

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SUMMARY

The present paper records the first of a series of investigations undertaken to give quantitative expression to the shrinkage of wool fabrics in a milling machine. The frictional resistance to motion of the wool fibre is smaller in the direction of the root-end than in the direction of the tip, and the difference between these two values of friction is taken as a measure of scaliness and of the effectiveness of the scales in causing shrinkage in milling. In the case of the dry fibre moving against a card wire, Barker and Marsh[1] have found the friction in the antiscalar direction to be 20% higher than in the direction of the scales. Measurement of the scaliness of different wools has not hitherto been attempted, nor has any method for performing such experiments been described. For any interpretation of the milling process, it is the friction of wool against wool which must be measured, and the present paper describes a method for making such observations, together with typical measurements of scaliness for a wide range of wools. Apart from its interest in relation to milling, it is believed that the method may be of service in biological studies of the inheritance of scale characters.

INTRODUCTION

Milling has been the subject of many investigations and although a number of different theories have been advanced to explain the shrinkage which wool fabrics undergo in the process, none of these has met with widespread acceptance. The only fibres to which the process can be successfully applied are those possessing a surface scale structure, and the conclusion seems inevitable that the scales are in some way directly responsible for the felting and shrinking of wool fabrics in a milling machine. It was at first thought that under the influence of pressure, moisture, and heat, the fibres are forced into intimate contact and retained in this formation by the interlocking of the scales of contiguous fibres. This view has now been abandoned, mainly on the grounds that microscopic examination of a milled fabric fails to reveal fibres showing such intimate scale contact. The generally accepted view of the manner in which scales promote milling shrinkage is based on the observations of Ditzel,[2] which have recently been confirmed and extended by Arnold.[3] These authors were able to show from experiments carried out with locks of wool, that when the fibres are subjected to longitudinal rubbing action, they tend to travel in the direction in which the scales do not oppose motion, i.e. in the direction of the root-end. When two locks were placed end to end, with their root-ends in contact, the action of the felting machine caused rapid interpenetration of the fibres from each lock, whereas when the tips were in contact, no interpenetration could be observed. It seems clear from these experiments that the fibres composing a wool fabric will similarly tend to travel in the direction of their root-ends under the action of the milling machine. It remained for Shorter[4] to show that such unidirectional freedom of motion could cause the shrinkage of fabrics. His explanation is, briefly, that fibres travelling in the direction of the root-end through a loose mass of fibres can carry along with them those fibres with which they are mechanically entangled. Under the action of the milling machine, there will therefore be a continuous tightening-up

of the structure with decrease in its surface area and increase of thickness as a result.

On the basis of the preceding view of the cause of milling, it is to be expected that the rate of shrinkage of a fabric in a milling machine will be determined by the magnitude of the difference between the frictional resistance to motion of a fibre in the direction of the root-end, and that in the direction of the tip, the friction being greater in the latter instance. In the absence of complicating factors, this difference in friction and the rate of shrinkage should be directly related. Such a view receives support from a comparison of the scale structure of, say, merino wool and mohair. As seen under a microscope, the former has well-defined scales projecting to a marked extent from the body of the fibre, whereas the scales of mohair are indistinct and adhere closely to the fibre throughout their length; as would be expected, therefore, merino wool felts far more rapidly than mohair under identical conditions of experiment. Although discrimination between the scaliness of different fibres is thus possible in the case of extreme types by purely microscopic observation, the method is of little use for comparing different wools. It is clearly necessary to have some measure of scaliness not only with a view to the ultimate quantitative expression of milling shrinkage, but also in connection with sheep breeding experiments having as their purpose the production of wools eminently suited to the process. The object of the present paper is to give a method for measuring the scaliness of wool fibres, but before proceeding to its description it is necessary to discuss other factors which *affect* the rate of shrinkage of wool fabrics in the milling machine.

As has already been indicated, similar fabrics made from different wools will shrink at very different rates on account of the different degrees of scaliness of the constituent fibres, but it is by no means certain that this is the sole reason for their different behaviour, as will be indicated later. In the case of any one wool, the rate of shrinkage of a fabric can be modified to a remarkable degree by changes in the conditions of milling. For example, the rate of shrinkage is least in water at the isoelectric point and increases with increase in the acidity or alkalinity of the milling agent. Data for acid solutions are given in illustration of this fact in Table I. Samples of fabric having an initial area of about 2,000 sq. in. were immersed in 4 litres of acid solution for 24 hours, and then milled in the fulling stocks for 2½ hours, using the acid solution with which the wool had come to equilibrium as the milling agent. The table shows the percentage reduction in area of the fabric produced in this time together with the *p*H of the milling agent used, the latter being determined potentiometrically by means of the hydrogen electrode.

Table I

Milling Agent	*p*H	Percentage Reduction in Area
Hydrochloric Acid	0·33	53·7
	0·95	51·6
	1·75	54·1
	2·37	51·5
	3·64	40·9
	5·00	37·4
Sulphuric Acid	0·33	50·5
	0·86	48·7
	2·77	40·3
Water	5·70	36·3

The increasing rate of shrinkage with increasing acidity or alkalinity of the milling agent suggests, by analogy with the properties of other proteins, that fibre swelling is a factor which affects the rate of shrinkage. It is by no means certain that different wools possess identical swelling properties, and their different behaviour in milling may in part be due to variations in the swelling factor. Discussion of the precise manner in which fibre-swelling is able to affect the rate of shrinkage of wool fabrics, and of the necessity for carrying out milling in presence of an aqueous solution (acid or alkaline), will be reserved for a later paper. One striking analogy, to which attention has not hitherto been drawn, appears to deserve comment. Although the data have not been published, Harrison[5] claims to have found that the shrinkage of wool fabrics, milled in presence of either soap or sulphuric acid, takes place most rapidly between 46° and 49° C. More recently, Davidson[6] has determined the apparent specific volume of *cotton* in water at different temperatures, and has found swelling to be a minimum at about 45° C. The identity of the critical temperature in the two instances may simply be a coincidence, but in view of the many broad similarities between the properties of the two fibres, wool and cotton, determinations of the swelling of wool in water at different temperatures have been undertaken. It is hoped that this investigation, together with determinations of the rate of shrinkage of wool fabrics at different temperatures, will serve to elucidate the very vexed question of the part played by fibre-swelling in the milling process.

Apart from these two factors, scaliness and swelling, the different felting properties of various wools may to some extent be determined by their different fibre lengths. Some account must also be taken of the recovery of fibres from a state of strain during milling, especially those possessing well-developed crimpiness. Finally, it must be recognised that whatever the nature of the wool, the rate of shrinkage of a fabric is largely determined by its yarn and cloth structure.

The present paper is concerned simply with the measurement of scaliness, and records the first of a series of investigations undertaken to give quantitative expression to the various factors involved in milling shrinkage.

EXPERIMENTAL

The principle adopted in the measurement of scaliness was to determine the frictional resistance to motion of wool fibres in the direction of the root-end, and in the direction of the tip. The difference between these two values of friction is taken as a measure of scaliness and of the effectiveness of the scales in causing shrinkage in milling. It is, of course, to be expected that different fibres, even from the same kind of wool, will show varying degrees of scaliness, and any method intended for the routine examination of a large number of wools ought preferably to average the properties of different fibres in the actual process of making a determination. With these considerations in mind, the following method of examining fibres was ultimately adopted.

The sample of wool to be used was extracted with alcohol and ether in a Soxhlet apparatus, washed with at least four changes of distilled water, and then allowed to dry. Fibres chosen at random from the sample were examined under the microscope and the direction in which the scales were pointing was ascertained. Fifty fibres were mounted with shellac on a small wooden bridge, similar to that shown in Fig. 1, sufficient tension

being applied to draw them just taut.* All had their scales pointing in one direction and were arranged as nearly parallel to the sides of the bridge and to each other as it was possible to judge by eye. The two small pieces of wood, shown at "A" in Fig. 1, served to raise the major portion of each

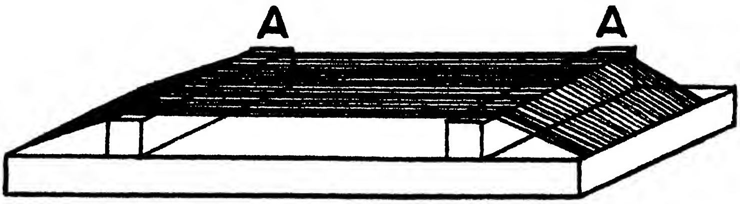


FIG 1

fibre so that the whole structure resembled the bow of a violin. The "bows" used in the first set of experiments measured 3 in. × 1 in. and the fibres were elevated for about 1·8 in. of their length. They were well-suited to the examination of long-fibred English wools but with shorter, merino, wools only the coarser fibres were long enough to be stretched over a bridge of these dimensions. Such wools necessitated the construction of smaller platforms measuring 2·3 in. × 1 in., the distance between the two strips of wood being 1·3 in. The average weight of the larger bows was 5·4 g. and of the shorter, owing to their being made of a heavier type of wood, 6·0 g. During the mounting, care was taken to avoid handling the fibres unnecessarily and to confine the handling as much as possible to the ends, in order to prevent contamination with grease from the fingers. The slide and cover-slip used in microscopic examination of the fibres were also kept free from grease by frequent washing in ether or acetone.

It is necessary at this stage to consider the nature of the surface along which the bows so produced shall be allowed to slide during friction measurements. Milling shrinkage takes place by the migration of fibres in contact with their own kind, and the ideal surface on which friction measurements should be made would be one composed of fibres of the same kind as those constituting the bow, the fibres being arranged parallel to one another with the scales all pointing in one direction. Using such a surface, measurements could be made with the scales of both bow- and surface-fibres opposing motion and with the scales in each case favouring motion. The difference between the two determinations of friction would then be the maximum possible in the case of any one wool, and would give a perfect measure of scaliness. Unfortunately, the diameter of wool fibres is so very small that the labour involved in constructing the surface is such as altogether to prohibit its use. Even if no attempt were made to arrange the fibres

*In the case of a skilled observer, the sense of touch is sufficiently delicate to allow fibres to be mounted at a uniform, minimum tension, especially when, as in the case of wools showing well-developed crimpiness, recognition of the condition of tautness is facilitated by visual observation More recently, Dr J. I. Hardy, working in these laboratories, has shown that it is immaterial, within fairly wide limits, at what tension the fibres are mounted, provided the finished bow is exposed to air saturated with water vapour for 24 hours before making measurements of scaliness. Under such conditions, the tension within the fibres decays rapidly and the process is fairly complete in the time specified.

with their scales all pointing in one direction, the tedium of constructing surfaces of this type would still be prohibitive. At the same time, it is clearly necessary, if the most useful results are to be obtained, that the surface used in friction measurements should be one composed of wool. Ultimately, a face cloth having a trail pile finish was chosen as the best possible compromise. A strip of the cloth was extracted with ether to remove grease, and then gummed to the face of a glass slide with the pile lying in the direction of movement of the bow. Two sizes of pads, corresponding with the small and large bows were used, their dimensions being 3·2 in. × 1 in. and 3·7 in. × 1·3 in. respectively.

It is important to recognise that the use of one standard surface for all measurements of friction will tend to cause different wools to approximate to one another in behaviour. For example, mohair fibres will show greater friction in contact with wool than in contact with mohair itself; while a wool showing more scaliness than that composing the cloth surface will reveal less scaliness than it possesses. Such deductions are substantiated by Speakman and Horner's[7] study of the milling shrinkage of blended wools. Two wools of widely different properties were chosen—80's merino and 56's Southdown—and blended in the following three proportions by weight—3 parts merino, 1 part Southdown; equal parts merino and Southdown; 1 part merino, 3 parts Southdown. Yarns of the same count and twist were manufactured from each of the three blends, and also from the original merino and Southdown wools. The five types of yarn were woven as weft on a cotton warp and, following scouring, the initial widths of the five pieces of cloth were measured. They were then milled for 45 minutes in rope form with soap in a milling machine and, after washing and drying, the final widths of the several pieces were measured. The percentage reduction in width for each type is given in Table II.

Table II

Blend	Percentage Reduction in Width
All Merino	43·2
3 parts Merino; 1 part Southdown	41·9
2 ,, ,, 2 parts ,, ...	41·3
1 part ,, 3 ,, ,, ...	35·1
All Southdown	26·3

It is a surprising discovery that the blending of an equal weight of Southdown wool with merino wool should have so little influence on its shrinkage properties. To some extent, this is due to the fact that quantities of Southdown and merino wools which are equal in weight are by no means equal in surface area; but even when due allowance is made for the coarseness of the Southdown wool (mean fibre diameter $= 32\cdot4\ \mu$) as compared with merino wool (mean fibre diameter $= 21\cdot0\ \mu$), it is still evident that Southdown wool is not capable of reducing the shrinkage of a blend to the extent which might be expected. The Southdown fibres, surrounded in large part by merino fibres, are clearly behaving very much as if they possessed the properties of the latter, i.e. the pronounced scaliness of the merino fibres improves the efficiency of the scales of the Southdown fibres with which they are in contact. Similarly, the blending of 25% by weight of merino wool with Southdown wool, improves the milling properties to a remarkable degree, an effect which is due not only to the efficiency of

the merino fibres themselves but also to their influence on the Southdown fibres with which they are in contact.

As previously stated, therefore, the use of one standard surface for all measurements of friction will tend to cause different wools to approximate to one another in behaviour. This is not to say that the comparison of different wools by means of a standard surface will be invalidated, but merely that the range of scaliness recorded will be reduced without affecting the relative positions of various wools in the series.

Apparatus and Procedure

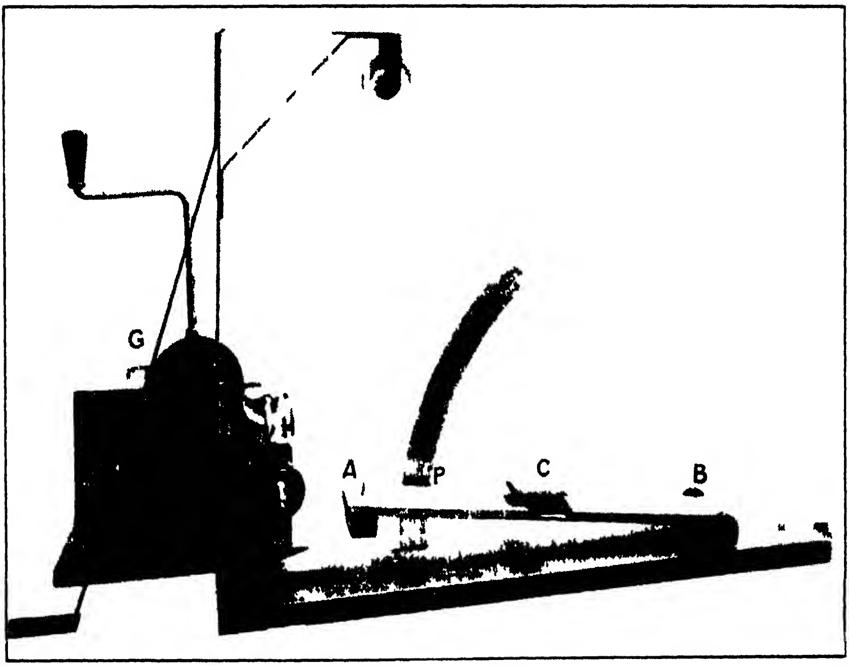
The apparatus used in making friction measurements is shown in the photograph (Fig. 2). It consists essentially of a platform *AB*, capable of rotation about a horizontal axis at *B*. After first adjusting the platform to be perfectly horizontal with the pointer *P* reading zero on the graduated arc, the pad was placed in position at *C* with the bow across it in the manner shown in the photograph. Care was taken always to set the base of the bow exactly parallel to the platform in both vertical and horizontal planes. The first measurement of friction, taken with the fibres sliding in the direction of the root-end, was made by determining the angle at which the bow slipped along the pad when the platform *AB* was inclined by means of the gramophone motor *G*. The latter was geared in such a manner that ascent of the platform took place extremely slowly, and the handle *H* afforded a ready means of interrupting the ascent at the moment of slip, so that the angle recorded by the pointer *P* could be read with precision. Afterwards, the platform was returned rapidly to its original position by means of suitable reversible gearing, operated through the arm *K*, and the direction of the bow was then reversed so that slip would take place with the scales *opposing* motion when the angle of slip was redetermined. In order to average possible irregularities in the surface of the pad, pairs of measurements were made with the bow at the front, middle, and back sections of the pad in turn. A typical set of measurements for an 80's quality Cape merino wool is given in Table III.

Table III

Load on Fibres = Wt. of Bow = 4·08 g.

Position of Bow on Pad	Angle of Slip in Direction of— Root	Tip
Middle	13·0	19·0°
Back	13·3	20·0°
Front	14·3°	18·0°
Middle	14·0	18·8
Back	13·0°	19·5
Front	12·3°	19 5
Middle	12·8°	18·5
Back	12·0°	19·0°
Front	14·0°	19·2°
Middle	13·0°	18·0°

Similar sets of measurements were made with the bow loaded by increments of about 5 g. up to 40 g., but it was found that the coefficient of friction for any one direction of slip decreased with increase of load. This is due to changes in the nature of the surface of the pad and, possibly, of the fibres with increasing load and leads to difficulty in finding a method for expressing the results for different wools in comparable terms. The various wools differ considerably in fibre diameter, and although the load



Fig

applied to the sets of 50 fibres during friction measurements may in all cases be identical, the effective load will vary as some inverse function of the mean fibre diameter. The exact nature of this function is difficult to determine and absolute measurements of friction are correspondingly difficult to interpret. It was, however, found that the difference between the two values for the coefficient of friction, obtained with the scales of the bow-fibres opposing and favouring motion, was completely independent of load when expressed as a percentage of the coefficient of friction observed when the scales were favouring motion. If θ_1, is the angle of slip with the scales favouring motion, and θ_2 the corresponding angle for the same position of the bow on the pad but with the scales opposing motion, the percentage difference in friction is given by the expression —

$$\text{Percentage difference in friction} = \left(\frac{\tan\theta_2 - \tan\theta_1}{\tan\theta_1}\right) \times 100.$$

Values for the percentage difference in friction were evaluated for each pair of readings and the mean percentage difference calculated from the ten values obtained for each load applied to the bow. The independence of this mean percentage difference in friction and the load is indicated by the data given in the following table.

Table IV

Wool	Load (grams)	Mean Percentage Difference in Friction
English Leicester	5·23 (wt. of bow) ...	13·7
	12·45	12·9
	18·73	12·7
	25·55	14·8
	34·15	13·6
	39·75	14·8
Tasmanian Super-quality Merino ...	5·85 (wt. of bow)	52·8
	12·02	49·2
	15·29	49·6
	19·12 ..	52·1

The percentage difference in friction can be used to compare the scaliness of different wools because, although the friction in the direction of the root-end may not be invariable, there will be a tendency for the value to rise with increasing scaliness. This was immediately evident in the case of extreme types like mohair and wool, and the use of "percentage difference in friction" to compare different wools will therefore tend to reduce the range of scaliness recorded, but without modifying the relative positions of various wools in the series.

It will be obvious that measurements of scaliness, carried out in the manner described above, will be valid only when the fibres constituting the bow do not show a pronounced taper in any one direction. Where tapering is in evidence, the percentage difference in friction will be higher or lower then the true value according to the direction of the taper. In the following examination of various wools, the diameter of each fibre in the bow was therefore measured at three points along the length—root, middle, and tip. Measurements were made by means of a microscope provided with a calibrated eyepiece micrometer, sufficient illumination for the purpose being obtained by inserting a mirror between the fibres and the base of the bow. The mean diameter of the 50 fibres was calculated

for each of the three positions, and the average of these values again taken to obtain a measure of the quality of the wool. Typical results are given in Table V to indicate the order of variation in diameter which was regarded as permissible.

Table V

Wool	Average Diameter (μ) at— Root	Middle	Tip	Mean Diameter (μ)
Australian 64's Merino ...	23·0	23·7	22·0	22·9
Mohair	31·8	31·6	32·3	31·9
English Leicester	38·5	37·6	38·0	38·0

Results

The following measurements of scaliness were all obtained by the above procedure, using bows constructed from 50 fibres selected at random. This number gives easily reproducible results, especially when selected from wool in the form of top, but even in the case of scoured wool the degree of reproducibility is surprisingly good, as shown by the following data for two bows constructed from the same Corriedale wool.

Bow No	Percentage Difference in Friction	Average Fibre Diameter (μ)
1	26·3	24·3
2	24·0	23·2

Each measurement of scaliness given in the following table represents the mean value for the percentage difference in friction derived from 40-50 pairs of measurements under four different loads. For convenience in subsequent discussion, the merino wools are classified in order of increasing fibre diameter, the remaining wools being arranged in order of decreasing scaliness.

Table VI

Wool	Percentage Difference in Friction	Average Fibre Diameter (μ)
1—Tasmanian Super-quality Merino ...	50·9	16·1
2—90's Australian Merino	42·9	17·4
3—80's ,, ,, ...	60·4	17·7
4—80's Cape Merino	52·0	18·3
5—70's ,, ...	59·4	19·0
6—70's ,, ...	60·0	19·4
7—64's ,, ...	52·0	20·8
8—64's ,, ...	44·3	21·4
9—70's Australian Merino	39·8	22·0
10—64's ,, ,, ...	44·0	23·0
11—60's ,, ,, ...	33·7	24·8
12—60's ,, ,, ...	35·0	27·4
13—Australian Merino	22·6	33·2
14—Southdown	28·3	32·8
15—Romney Marsh	27·5	34·3
16—56's Southdown	25·7	31·7
17—Corriedale	25·2	23·8
18—Exmoor	23·5	40·9
19—Oxford Down	21·3	41·7
20—Wensleydale	16·3	36·8
21—Leicester	13·5	38·0
22—Mohair	5·0	31·7

Although two reasons have been given in the preceding discussion for supposing that the range of scaliness recorded by the present method will be less than that theoretically possible, it is evident that the method is

still extremely sensitive. Assuming that the percentage difference in friction is one of the determining factors in milling, the values obtained for merino wool and mohair are in good agreement with the recognised milling properties of the two types. The frictional differences obtained in these two cases represent the limiting values for the series, other wools being intermediate in type. The order in which they occur, however, is not strictly that which would be expected from their felting properties For example, Speakman and Goodings[8] found the following values for the percentage shrinkage in area of cloths possessing the same structure, milled for the same time under identical conditions, but made from different wools—

Wool		Percentage Shrinkage in Area
Wensleydale	...	33·7
Oxford Down	..	28·0
Southdown ...	...	16·3

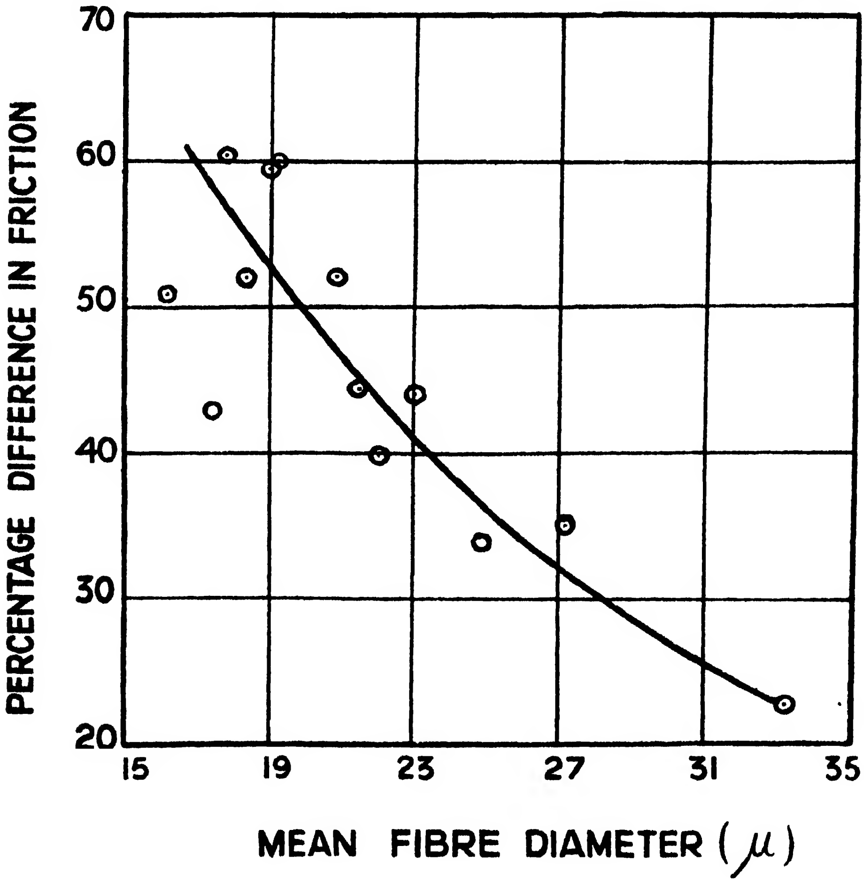


Fig 3

The wools in question were those used in measurements of scaliness and reference to Table VI indicates that the order of milling efficiency is exactly the inverse of the order of scaliness. Evidently in these cases properties other than scaliness determine milling efficiency, whereas with

merino wool and mohair, the scales on the one are so pronounced and on the other so ill-defined as to make scaliness the dominating factor in determining their relative milling properties. Wools intermediate in type do not appear to differ sufficiently in scaliness to allow of this being the predominating cause of shrinkage differences.

The results for merino wools were obtained with the shorter type of bow already described, and are in this respect distinct from the rest. Experiments carried out with long and short bows constructed from Wensleydale wool served, however, to show that the distinction has no real significance the two sets of results being in every way comparable with one another. Although the list of merino wools includes several having the same quality numbers, it must be emphasised that they were all totally distinct samples. There is an evident tendency, illustrated in Fig 3, for scaliness to increase as the quality of the wool increases, with the possibility of a decrease beyond 80's quality. This decrease may be due to the fact that the two very fine wools used had longer fibres than are usually to be found in such qualities, and the result may not be typical of fine wools in general. Up to 80's quality, however, there is a well-defined rise of scaliness with quality, and the result is in keeping with the general trade impression that the milling efficiency of merino wools improves with quality. The realisation of this connection between milling properties and scaliness is dependent on the fact that the various wools studied are merely different qualities of the same type of fibre. In such a case, there is far less likelihood of other factors masking any relation between scaliness and milling properties than there is in a comparison of different types of wool.

In conclusion, it may be stated that a true forecast of the relative milling properties of different wools can not be made unless their scaliness has been measured, their swelling properties investigated and the influence of fibre-length on milling determined. The present paper represents the first of a series of investigations undertaken to give quantitative expression to the various factors involved in milling shrinkage; it describes a method for measuring the scaliness of wool fibres. Marked differences in the scaliness of various wools have been revealed and their different milling properties must, to some extent at least, be referred to this cause. No strict correlation between scaliness and milling efficiency ought, however, to be expected in the case of radically different types of wool because scaliness is not the only factor concerned in the milling process. Part II of this paper will be devoted to a discussion of the two remaining factors which may affect the relative milling properties of different kinds of wool—fibre-swelling and alterations in scaliness caused thereby, and fibre-length.

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TRANSACTIONS

22—THE SWELLING OF CELLULOSE AND ITS AFFINITY RELATIONS WITH AQUEOUS SOLUTIONS. PART IV. THE PREFERENTIAL ABSORPTION OF BARIUM HYDROXIDE AS A CHARACTERISTIC PROPERTY OF CELLULOSE AND AN INDICATION OF PREVIOUS MERCERISATION OR OTHER SWELLING TREATMENT

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INTRODUCTION AND SUMMARY

It was shown in a previous paper* that the state of "activation" of cellulose that results from pretreatment with swelling agents could be characterised by the enhanced absorption of sodium hydroxide from dilute solution. The object of the present communication is to show that the absorption of barium hydroxide affords similar information, but since this absorption is greater in amount it can be estimated relatively more exactly. The experimental procedure is similar to that adopted for the soda absorption, but the standard reagent strength is one quarter normal and the absorptions are referred to a fixed end concentration of one fifth normal. It is convenient to express the results as the "baryta absorption ratio," relative to the amount of barium hydroxide absorbed by plain scoured cotton from a solution of the same end concentration at the same temperature. This ratio is, for samples of cotton of widely different pretreatment, almost indistinguishable from or perhaps slightly higher than, the soda absorption ratio.

It is also—like the soda absorption ratio—itself substantially independent of the reagent concentration. These facts lend additional significance to the alkali absorption ratios as measures of the relative amount of accessible salt-forming hydroxyl which is rendered available when cellulose is swollen, washed, and dried.

From the technical point of view, as a possible control of the mercerising process, measurement of capacity for absorbing baryta is to be preferred to the soda absorption since the determination is less exacting. While the absorption ratio might perhaps be used as a check on the regularity of a standard mercerised product, it cannot be relied on as a direct measure of any quality of textile value, nor, in the present state of knowledge, can its relation to such qualities be defined.

On account of its possible utility a suggested standard routine for the baryta absorption test is given in the appendix.

EXPERIMENTAL

The experimental method is exactly similar to that described in the previous paper for the determination of soda absorption. A weight of the sample containing 2 g. of dry cotton is allowed to stand overnight with occasional shaking in 30 c.c. of barium hydroxide solution, and 10 c.c. are then withdrawn for titration with standard acid. The amount of alkali preferentially absorbed

* J. Text. Inst., 1931, **22**, 1320–1338.

is calculated from the change in titre, with the appropriate corrections for dilution by moisture content and for differences in temperature between alkali and acid, just as for the absorption of sodium hydroxide. The standard reagent is quarter normal barium hydroxide and the standard temperature is 25° C.

(1) Effect of Temperature

Measurements made in thermostats at various temperatures, the standard quarter normal reagent being used, led to the results given in Table I.

Table I

Preferential Absorption, Milli-equivalents per 162 Grams of Cellulose

Temperature C ..		0	15 17	20	25	35
Scoured Sakel yarn ..	(S)	94·4 94·2	81·9 82·3	77·4 77·6	75·6 75·4	70·7 70·0
Above yarn treated 25% NaOH, washed, air dried ...	(M)	195 5 195·1	183·1 181·1	170·0 169·3	.. ...	157·6 158·0
Ratio	(M S)	2·07	2·22	2·19	..	2·24

The amount of barium hydroxide absorbed falls as the temperature rises, but the last row of figures shows that the relative increase in absorbing power resulting from pretreatment with concentrated caustic soda solution is independent of the temperature of experiment over the range 15° to 35° C. It should be noted that this ratio is not that which will be called the "baryta absorption ratio"; the latter refers to measurements corrected to a constant end concentration in the manner to be indicated in the following section.

(2) The Effect of Reagent Concentration

The previous paper described how the absorption of sodium hydroxide varied with the concentration for a scoured yarn, a technically mercerised cloth, a yarn pretreated with concentrated alkali, and a cuprammonium rayon. The same four samples of cellulose were used to determine the effect of the concentration of barium hydroxide on the amount absorbed. In all

Table II

	Initial concentration	Final concentration	Preferential absorption milli-equivalents per 162 g of cellulose	
	Equivalents per litre			
Sakel yarn scoured with 1% NaOH at 20 lb excess pressure for 6 hours	·346 ·2499 ·0966	·307 ·2175 ·0814	92·4 75·1 36·0	92·0 74·9 36·2
Technically mercerised poplin cloth	·346 ·2500 ·0966	·284 ·1997 ·0728	145·6 118·4 55·9	146·3 118·8 56·1
Above yarn treated loose with 25% NaOH solution, washed, dried at laboratory temperature	·346 ·2465 ·0966	·249 ·1695 ·0624	228·5 181·0 80·5	228·0 182·0 81·0
Cuprammonium rayon ...	·346 ·346 ·2500 ·1002	·276 ·225 ·1549 ·0582	333·4 288·5 226·1 100·1	336·0 288·9 226·3 99·8

cases 2 g. (dry weight) of the sample were immersed in 30 c.c. of baryta solution at 25° C., except that in the most concentrated solution the rayon absorption was also measured at the ratio 1 g. to 30 c.c. The results are given in Table II and are plotted in Fig. 1.

(3) The Correction of the Observations to a Fixed End Concentration, and their Expression as Baryta Absorption Ratio

The preferential absorptions of baryta as determined are not strictly comparable quantities, since they evidently refer to equilibria with solutions of varying concentration. From Fig. 1, however, corrections may be deduced

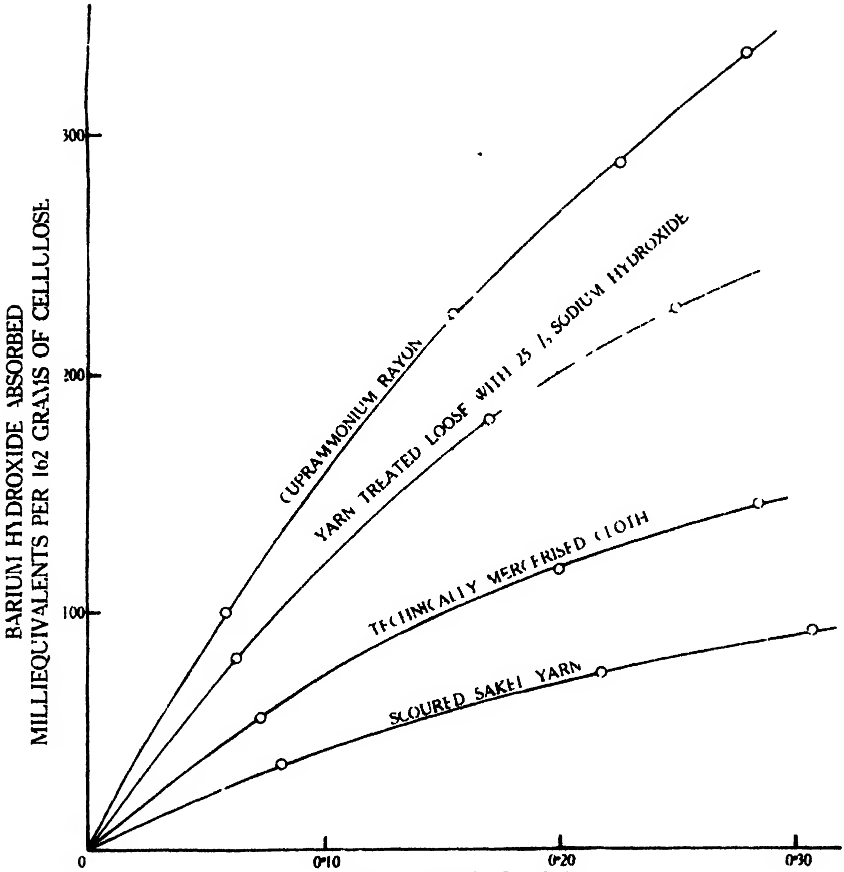

FIG. 1

applicable to experiments made with 2 g. of cellulose and 30 c.c. of quarter-normal baryta, the observed absorption being converted to that to be expected if the end concentration were always fifth normal. These corrections are given in Table III and a curve drawn through them is shown in Fig. 2. The absorption so corrected to a fixed end concentration is for convenience of expression usually divided by the corrected absorption characteristic of scoured natural cotton (71·0 milliequivalents at 25° C.) and the quotient is called the "baryta absorption ratio."

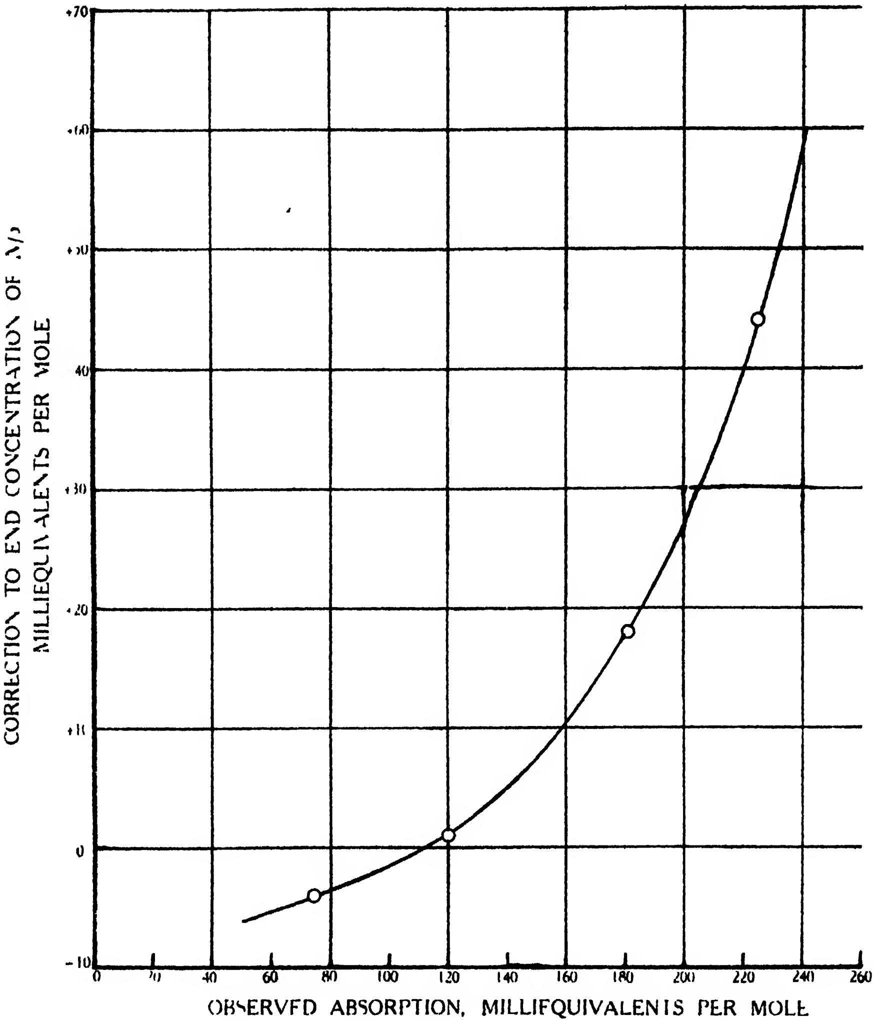

Fig 2

Table III

	Absorption of $Ba(OH)_2$ milli-equivalents per 162 g Observed	Corrected to $N/5$	Baryta absorption ratio
Scoured Sakel yarn (not the same as in Table IV)	75·0	71·0	1·00
Technically mercerised cloth	118·6	119·6	1·68
Yarn treated loose with 25% caustic soda, air dried	183	201	2·82
Cuprammonium rayon	226	270	3·80

(4) The Baryta Absorptions Characteristic of Cottons of Different Growths, before and after Mercerising

A number of yarns were spun to 2/50's from different varieties of cotton, and a portion of each was mercerised according to technical practice by wetting out, immersing in 24% caustic soda solution on the mercerising machine so as to allow 4% contraction in length, restretching, washing, and air drying. The samples both grey and mercerised were then scoured together for six hours at 20 lb. excess pressure in 1% caustic soda, soured, washed, and air dried. The baryta absorption of each sample was then determined in the standard manner, except that the absorption took place at an uncontrolled laboratory temperature of 16° to 18° C. On this account the baryta absorption ratios have been calculated relative to an absorption of 79 milliequivalents, the mean for scoured cotton at that temperature. The results are given in Table IV and the soda absorption ratios are included for comparison.

Table IV

Variety of Cotton	Hair Weight mg./cm. × 10^5	Scoured only: Baryta absorption: Milli-equivalents corrected to end concentration N/5	Scoured only: Baryta absorption: Ratio	Scoured only: Soda Absorption Ratio	Mercerised and Scoured: Baryta Absorption Ratio	Mercerised and Scoured: Soda Absorption Ratio
Egyptian Sakellaridis	149	74·0	0·94	0·95	1·57	1·57
Egyptian Uppers	196	75·0	0·95	0·95	1·61	1·57
Brazilian	164	77·8	0·985	0·97	1·66	1·62
Tanguis	212	78·7	1·00	1·01	1·66	1·63
Arizona (immature)	107	80·7	1·02	1·02	1·70	1·63
Peruvian Mitafifi	202	86·5	1·09	1·08	1·66	1·68

It will be seen that the absorption does not vary greatly from one variety to another, nor is there any evidence that the fineness of the hairs exerts any effect. On the other hand, both soda and baryta absorption, on both mercerised and unmercerised cotton, place the samples in substantially the same order. Table IV is, however, mainly of value in showing that the effect of variety of cotton is relatively small.

(5) The Baryta and Soda Absorption of Sakel Yarn, Mercerised in Grey and Scoured States with Caustic Soda Solutions of Different Concentrations, with and without Tension

The scouring treatment applied to the samples described under this heading was boiling for six hours at 20 lb. excess pressure with 1% caustic soda solution. The mercerisation was done on a hank mercerising machine, and the temperature of the mercerising alkali was about 25° C. Each hank or set of hanks, to be mercerised in the grey state, was thoroughly wetted by boiling with a 1% solution of Turkey Red oil just before it was placed on the machine rollers. The yarns were in contact with a large excess of the mercerising alkali for three minutes in all, but the "loose and re-stretched" samples

were allowed to shrink freely during the first two minutes and were restretched to grey length during the last minute. After three minutes the alkali was washed off with cold water, the yarns were scoured for half an hour in $N/5$ hydrochloric acid, washed for several days in many changes of distilled water, and dried in the air at laboratory temperature. Samples were taken for the determination of baryta and soda absorption in the standard manner at 25° C.; the absorption ratios are given in Table V, and are plotted against the concentration of the mercerising alkali in Fig. 3.

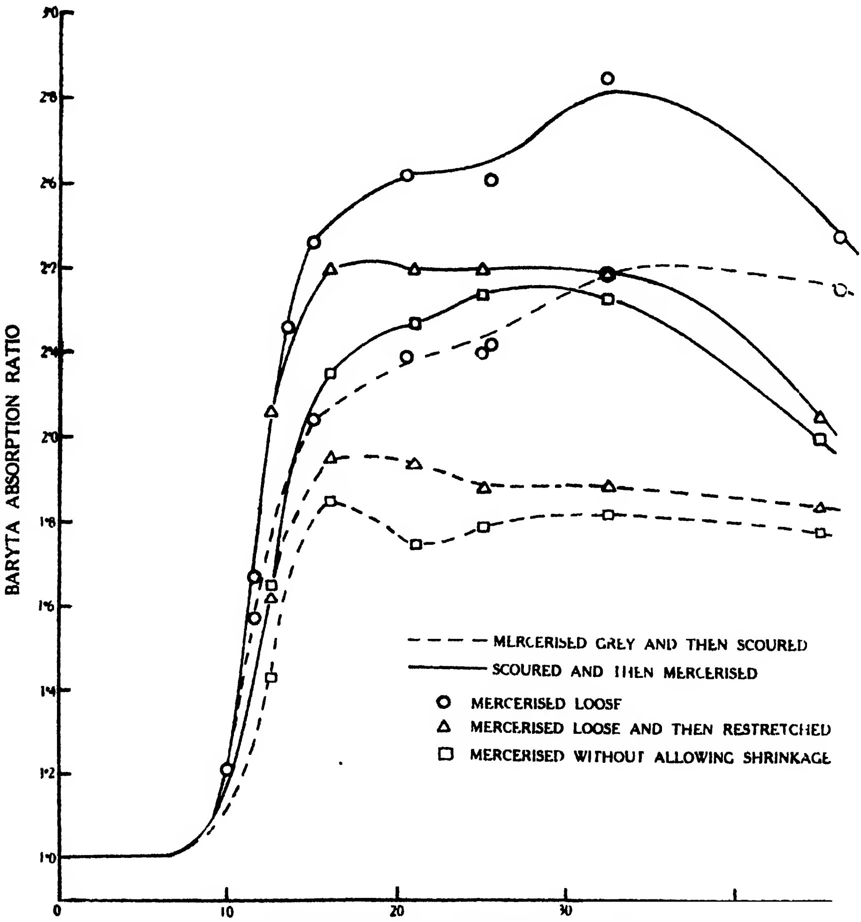

FIG. 3

The fact that the curves for cotton mercerised in the grey and scoured states cross at high alkali concentrations is no doubt to be attributed to the local dilution of the concentrated alkali by the wetting liquor entrained in the grey cotton.

Table V

Effect of Conditions of Mercerising on the Alkali Absorption Ratios of Mercerised Yarns (Grey Yarns Wetted Out before Mercerising, all 3 mins. in the Alkali, Washed with Cold Water, Air Dried)

Concentration of mercerising liquor, g NaOH per 100 g. solution	Scoured—then Mercerised						Mercerised Grey then Scoured					
	Loose		Loose and restretched		No shrinkage		Loose		Loose and restretched		No shrinkage	
	Alkali Absorption Ratios											
	Na	Ba	Na	Ba	Na	Ba	Na	Ba	Na	Ba	Na	Ba
10·0	1·28	1·21	...	...	...	...	...	...	...	...	...	...
11·6	1·58	1·67	...	...	...	...	1·51	1·57	...	...	...	...
12·5	...	...	1·92	2·07	1·60	1·65	...	...	1·61	1·63	1·41	1·43
13·4	2·28	2 26	...	...	...	...	...	...	...	...	...	...
15·0	...	2·46	...	...	...	...	1·86	2·04	...	...	...	
16·0	...	...	2·30	2·40	2·07	2·16	...	...	1·95	1·95	1·73	1·85
20·5	2·39	2·62	...	...	...	...	2·02	2·19	...	...	...	...
21·0	...	...	2·30	2 41	2·18	2·28	...	...	...	1·94	1·68	1·75
25·0	...	...	2·34	2·40	2·23	2·34	2·09	2·20	1·85	1·88	1 75	1·79
25·5	2 47	2·61	...	...	...	...	2·13	2·22	...	...	...	...
32·0	...	...	2·28	2·40	2·24	2 33	...	...	1·86	1 89	1·85	1·82
32·4	2·58	2·86	...	...	...	...	2·29	2·39	...	...	...	...
45·0	...	...	1·90	2·06	1·84	2·01	...		1 85	1·84	1·76	1·78
46·0	...	2·48	...	...	...	...	2·17	2·34	...	...	...	...

THE CORRELATION BETWEEN SODA AND BARYTA ABSORPTION RATIOS

It has been shown in this and the previous paper that these ratios are characteristic constants of a cellulose material, in that they are independent of the particular reagent concentration used in their determination, up to the point where the reagent itself swells the cellulose. If it should turn out that the absorption ratio of any sample had the same value whether determined with sodium or with barium hydroxide, this would not only add to the significance of the alkali absorption tests, but would also make it seem probable that sodium and barium react with cellulose in fundamentally similar ways. Such similarity of reaction type might be expected if sodium and barium both react with formation of a salt. The fact that the amount of the baryta absorption is, at the same equivalent concentration, so much greater than the soda absorption cannot, however, be explained on this simple basis. The question will be further examined at a later date.

Apart from this difference in the absolute value of the absorption, however, the data presented in Tables IV and V of this paper show that the two alkali absorption ratios (relative to plain scoured cotton) of cottons mercerised under the widest variety of conditions are very roughly identical. There is a small but definite tendency for the baryta ratio to exceed the soda ratio as the value of both ratios rises. The data given in Table IV of the following paper, and in Table X of the previous paper, indicate that the approximate identity of the two ratios holds for samples pretreated with various swelling agents, whether dried at high or low temperature. It has not been found possible to detect by examination of the data any factor in the pretreatment that leads to a systematic difference between the absorption ratios.

APPENDIX

SPECIFICATION OF SUGGESTED STANDARD ROUTINE FOR DETERMINATION OF BARYTA ABSORPTION OF COHERENT CELLULOSE

Determine the moisture regain of the sample of cellulose, say r g per 100 g. dry material. Take $2(1+ \cdot 01r)$ g. of the sample, and shake overnight in 30 c.c. of a $N/4$ solution of barium hydroxide maintained at 25° C.

Withdraw 10 c.c. of the baryta solution from the reaction vessel and titrate with $N/10$ or $N/20$ hydrochloric acid, using methyl red as indicator.

Correct the titre so obtained for the fact that the baryta is just below 25° C., the acid at room temperature. The temperature of the baryta is calculated from the heat content and capacity of the pipette. From this and the thermal expansion of water, the correction, which is small, is easily obtained.

Correct the initial titre for dilution by the moisture introduced with the sample.

Calculate the amount of baryta absorbed by 2 g of dry cellulose from the difference between these corrected titres

With the help of a graph constructed from the data of Table III, correct the absorption to that to be anticipated when the end concentration is $N/5$.

Divide this corrected absorption, expressed in milliequivalents per 162 g. of dry cellulose, by the figure 71 to obtain the absorption ratio relative to plain scoured cotton

Most of the experimental work was done by Mr R. Waite

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23—THE SWELLING OF CELLULOSE AND ITS AFFINITY RELATIONS WITH AQUEOUS SOLUTIONS. PART V—THE ABSORPTION OF COPPER FROM DILUTE CUPRAMMONIUM HYDROXIDE AS A CHARACTERISTIC PROPERTY OF CELLULOSE AND AN INDICATION OF PREVIOUS MERCERISATION OR OTHER SWELLING TREATMENT. A NEW CATALYTIC METHOD FOR MICRO-ESTIMATION OF COPPER

By Thomas Brownsett, Frederick Denny Farrow, M.Sc., and Sidney Maurice Neale, M.Sc.
(The British Cotton Industry Research Association)

INTRODUCTION AND SUMMARY

In the two previous papers* of this series it was shown that the capacity of cotton cellulose to absorb either sodium or barium hydroxide from dilute solution is greatly increased as a result of pretreatment with swelling agents. Following a treatment in a loose state with sufficiently concentrated sodium hydroxide solution, the absorptive power rises about 2·6 fold. The result of a similar treatment on the capacity to absorb water vapour from atmospheres of varying humidity has been investigated by Urquhart and Williams,[5] but the observed increase did not exceed 1·7 fold. This large difference in activation ratio could be explained on the assumption of different permeabilities of a cellulose network towards water and alkalis, or by the reasonable postulate that the alkalis react with only one of the cellulose hydroxyl groups, the water with all three, while the swelling treatment leads to a relatively greater increase of the number of free mutually unsaturated hydroxyls of the salt-forming type. If this latter explanation is accepted, and also the contention of Hess and Trogus[2] that the reaction with cuprammonium hydroxide, especially in the presence of sodium hydroxide, involves the two non-salt-forming hydroxyls, then the activation ratio as measured by reactivity towards cuprammonium hydroxide should be low. The obvious method of determination is that of the absorption of copper from dilute cuprammonium, and the present paper deals with this measurement. The results of Hess and Trogus[3] indeed indicate that the absorption of copper from cuprammonium containing sodium hydroxide is not to a great extent dependent on the cellulose or on previous mercerisation, but since the solutions they have employed to establish this point are so concentrated as to swell cellulose, it is hardly surprising that the observed absorption is not greatly affected by a previous swelling treatment It has been found, in agreement with Hess and Trogus, that the addition of sodium hydroxide to cuprammonium increases the amount of copper absorbed by a given sample of cellulose. By the use of a solution sufficiently concentrated in copper, the statement of Hess and Trogus that different celluloses absorb roughly similar amounts of copper has been confirmed.

The standard reagent employed in the present work, however, is too dilute to swell cellulose appreciably, and its use leads to the result that the copper absorption, either in the presence or absence of sodium hydroxide, is dependent on the pretreatment of the cellulose in much the same way as are the soda and baryta absorptions. The copper absorption of scoured cotton rises about 2·6 fold after treatment in a loose condition with 25% caustic soda, and thus the determination has failed to substantiate the speculation based on the views of Hess and Trogus with regard to the reaction with copper. Though

* J Text Inst, 1931, 22, 1320–1338 and 1349–1356

the approximate identity of soda, baryta, and copper absorption ratios is a noteworthy fact, it does not as yet form a basis for any satisfactory speculations.

The method here described for the determination of the copper absorption of cellulose may have technical utility where only small samples of the order of 10 mg. are available.

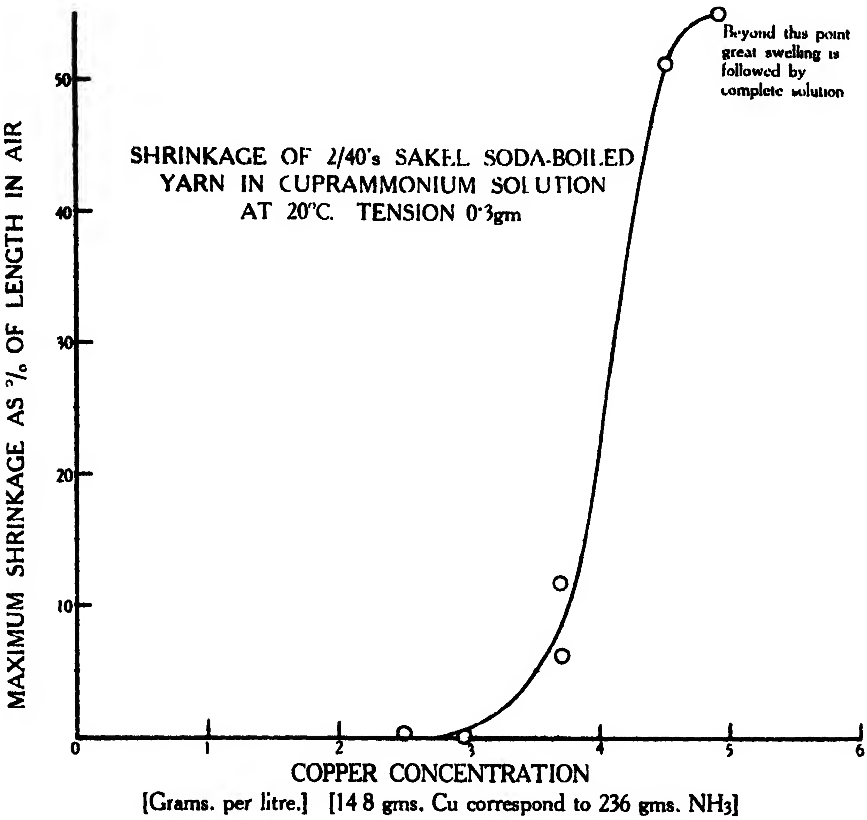

Fig. 1

EXPERIMENTAL

Development of a Method

(*a*) *Choice of a Reagent Concentration*—Since the present object in the determination of copper absorption is that of estimating the activation of cellulose resulting from pretreatment with swelling agents, it is evidently necessary to employ a reagent that exerts on the cellulose no appreciable swelling effect of its own. Since the material is highly anisotropic, the shrinkage in length of cotton yarn offers a convenient indication of the earlier stages of the swelling of this type of cellulose. To determine a permissible concentration, therefore, the shrinkage of 2/40's scoured Sakel yarn under 0·3 g. load was measured in cuprammonium solutions of different concentrations. The results of this measurement are given in Fig. 1, and from these it has been concluded that a solution containing less than 2·5 g. of copper per litre has no appreciable swelling effect. The solution adopted as the standard reagent has a concentration of 1·85 g. of copper (0·0581*N*), 28·5 g. of ammonia, and 0·02 g. of nitrous acid per litre, and is prepared from the standard reagent

used at this Institute as a cellulose solvent for viscosity determination by diluting it with water to eight times its original volume.

(*b*) *The Estimation of Copper Absorbed*—In the procedure first tried, 2 g. of cotton were added to 30 c.c. of the cuprammonium solution, and the preferential absorption of copper was estimated by analysis of the residual solution by the usual potassium iodide-thiosulphate volumetric method. On account of the unreliability of the starch end point, and because a method using only small amounts of cotton was desired, the amount of cotton taken was reduced to 40 mg. and the volume of solution to 0·60 c.c. The copper content of 0·20 c.c., measured out within 0·5% by a special micro-pipette, was estimated by various catalytic methods. The method of analysis finally chosen is described later, and is unusually accurate amongst catalytic methods owing to its sharp end point.

Since the copper absorption is very pronounced, so that the copper concentration sometimes fell to less than half of its original value, it was not found practicable to correct absorptions to a fixed end concentration, as for the soda and baryta absorptions. To overcome this difficulty and to avoid the labour of using the micro-pipette, a method was therefore finally adopted in which about 10 mg. of cotton were immersed in a large excess of solution, the adhering liquor was removed from the cotton by means of filter papers, and the copper actually in the sample was estimated. The procedure is described in detail in the sequel. It is characteristic of cuprammonium that its swelling action on cotton is very slow, presumably on account of the slow diffusion of copper, and this slowness of diffusion operates to prevent serious loss of copper from the cotton cellulose to the filter paper. The validity of this procedure is demonstrated by the following data, the regain figures showing that an excessive amount of solution is not retained after blotting, while the comparison with centrifuging shows that copper is not lost to the blotting paper. The copper absorption is so strong that a variation of 50% (on the weight of cotton) in the weight of solution retained would cause an error not greater than 3% on the observed copper absorption.

Absorption of Copper (Millimoles per 162 grams) by Mercerised Cotton Cloth

Dried by centrifuging	Weight of solution retained per 100 of cotton ...	100	95	90
	Copper absorption found	108	113	108
Dried by blotting	Weight of solution retained per 100 of cotton ...	43		45
	Copper absorption found	117		112

The discrepancies here do not represent the unavoidable error; the above measurements were among the first made, and the absorptions were not conducted at controlled temperature.

Method Finally Adopted

(*a*) *The Absorption Process* About 10 mg. of the sample are weighed on a torsion micro-balance, immersed in a volume of cuprammonium calculated on the basis of 15 c.c. to 10 mg. of dry cellulose, and allowed to stand in this solution at 20° C. with occasional shaking for at least four hours. The sample is removed from the cuprammonium, immediately blotted between sheets of filter paper, and then dried in an oven for a few minutes to drive off ammonia.

(*b*) *The Estimation of Copper*—The method used for the estimation of copper is a development of that employed by Baines,[1] but gives a much sharper end point. It depends on the fact that the reaction between sodium thiosulphate and hydrogen peroxide is accelerated by the presence of traces of copper. This reaction proceeds according to the following equation,

provided that the alkali is neutralised as soon as it is formed[4] -

$$2Na_2S_2O_3 + H_2O_2 = Na_2S_4O_6 + 2NaOH$$

If the alkaline hydroxide is not neutralised immediately it reacts with the tetrathionate, forming thiosulphate, sulphate, and sulphite.[4] A convenient measure of the rate of production of alkali can be obtained by adding a standard quantity of acid, and observing the time required for the solution to become alkaline A standard curve is obtained by determining the acceleration when known amounts of copper are present, and hence the method does not depend on the validity of the above equation It should be noted that the oxidation of thiosulphate by hydrogen peroxide is catalysed by traces of iron, which was not present in the materials dealt with in this paper

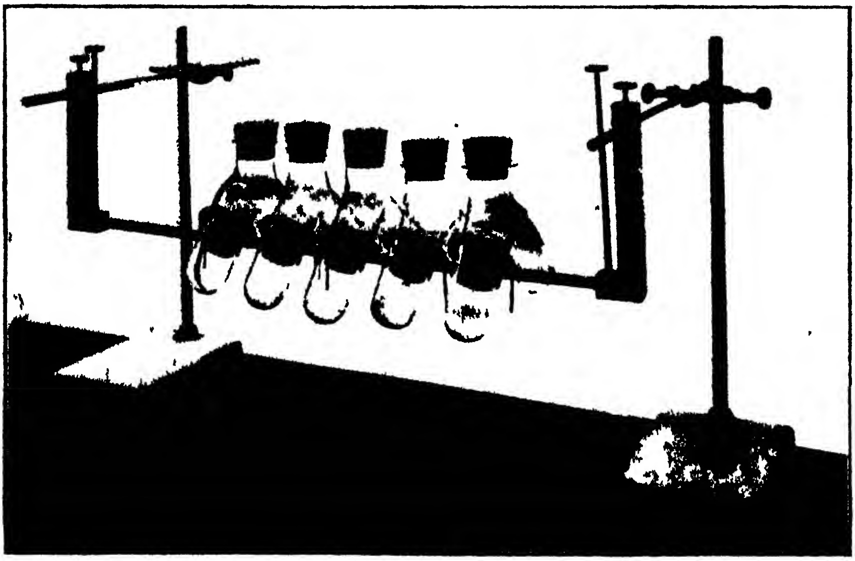

PLATE I

Photograph of bar with mixing tubes in position The apparatus is immersed in a glass-fronted thermostat with the stands outside

The determination is made in a mixing tube shaped like an inverted Y and stoppered with a well-fitting rubber stopper Into one limb of the tube 25 c.c of $N/10$ sodium thiosulphate are pipetted, and three or four drops of bromocresol purple are added. Into the other limb 10 c c of $N/10$ hydrochloric acid are run, the sample containing the copper is added, and finally 25 c c. of $N/4$ hydrogen peroxide are introduced The tube is then stoppered and allowed to reach temperature equilibrium in a 20° C thermostat It has been found convenient to clamp several of these tubes to a brass bar so that a number of determinations can be started at the same time A photograph of the bar with tubes in position is given in Plate I The solutions are mixed by a partial rotation of the bar, which tilts the vessels and allows all the contents to run into one limb or the other. This is done several times to ensure thorough mixing, and the time which elapses between the first tilting of the bar and the colour change is measured with a stop watch The colour change, which is yellow to purple, is very sharply defined, and can easily be timed to less than a second. Indeed, for reaction times of about 50 seconds, the change

is almost instantaneous. The time depends on the concentration of the hydrogen peroxide, and therefore a blank experiment, that is one containing no copper, is done along with each batch of determinations.

If the blank time is designated T_0 and the time when copper is present T_{Cu}, the quantity T_0/T_{Cu} is a measure of the amount of copper present. It will, in fact, be shown later that $T_0/T_{Cu}-1$ is proportional to the concentration of copper. The factor of proportionality between $T_0/T_{Cu}-1$ and the copper concentration is not very sensitive to changes in the blank time, so that the above procedure allows with sufficient accuracy for slight changes in blank time due to spontaneous decomposition of the stock hydrogen peroxide.

In the determination of the relationship between copper concentration and rate of reaction, it is necessary to perform the experiment in the standard fashion, adding small but accurately known amounts of copper without diluting the system. This is achieved by diluting 10 c.c. of a solution of copper sulphate containing 0·05 g.mole of copper per litre to 200 c.c. with $N/10$ hydrochloric acid. The diluted solution then contains $2{\cdot}5 \times 10^{-6}$ g.mole of copper per cubic centimetre. In a calibration experiment, x c.c. of the copper solution and $10-x$ c.c. of $N/10$ hydrochloric acid are used. The dilution of the acid caused by the copper sulphate in the calibration experiment is then exactly equivalent to that in the subsequent copper determination caused by neutralisation of part of the acid by the copper, which is then in the form of hydroxide. The graph of T_0/T_{Cu} against the amount of copper present is a straight line for any one concentration of peroxide, but its slope varies slightly with the peroxide concentration. It is found more convenient to renew the hydrogen peroxide when the blank time differs by more than about 10% from the standard time than to work with several standardising graphs. The results of two sets of standardising experiments are given in Table I and Fig. 2.

Table I

Calibration Data for Catalytic Micro-estimation of Copper

Hydrogen peroxide solution No. 1 (blank time about 480 secs.)

10^{-6} Moles Cu present c	0	10	15	25	0	5	12·5	20
Time (secs.)	479·6	112·2	75·4	47·9	477·6	173·0	101·8	59·2
T_0/T_{Cu} r	1	4·27	6·37	10·0	1	2·764	4·69	8·07
$(r-1)/c$	—	·327	·358	·360	—	·353	·295	·353

10^{-6} Moles Cu present	0	10	12·5	20	5	10	12·5	15
Time (secs.)	477·5	104·6	89·5	59·5	174·4	105	89·4	77·2
T_0/T_{Cu}	1	4·56	5·34	8·03	2·74	4·55	5·35	6·18
$(r-1)/c$	—	·356	·347	·351	·348	·355	·347	·346

10^{-6} Moles Cu present	0	7·5	15	0	5
Time (secs.)	480·0	133·0	77·4	520, 525	188, 188
T_0/T_{Cu}	1	3·61	6·21	1	2·77, 2·77
$(r-1)/c$	—	·348	·348	—	·354, ·354

Hydrogen peroxide solution No. 2 (blank time about 360 secs.)

10^{-6} Moles Cu present	0	1·25	2·5	3·75	5	0	12·5	12·5	25
Time (secs.)	350	248	192	157·6	133·2	356	71	66	38·5
T_0/T_{Cu}	1	1·41	1·82	2·22	2·62	1	5·02	5·39	9·25
$(r-1)/c$	—	·328	·328	·325	·324	—	·322	·352	·330

The constancy of the expression $(r-1)/c$ indicates that the relation between the amount of copper present and T_0/T_{Cu} can indeed be represented accurately by a straight line (see Fig. 2).

Since the graph is a straight line, it is more accurate to multiply $T_0/T_{Cu}-1$ by the factor of proportionality than to read the amount of copper off the graph. If the blank time does not equal either of the standard times, the

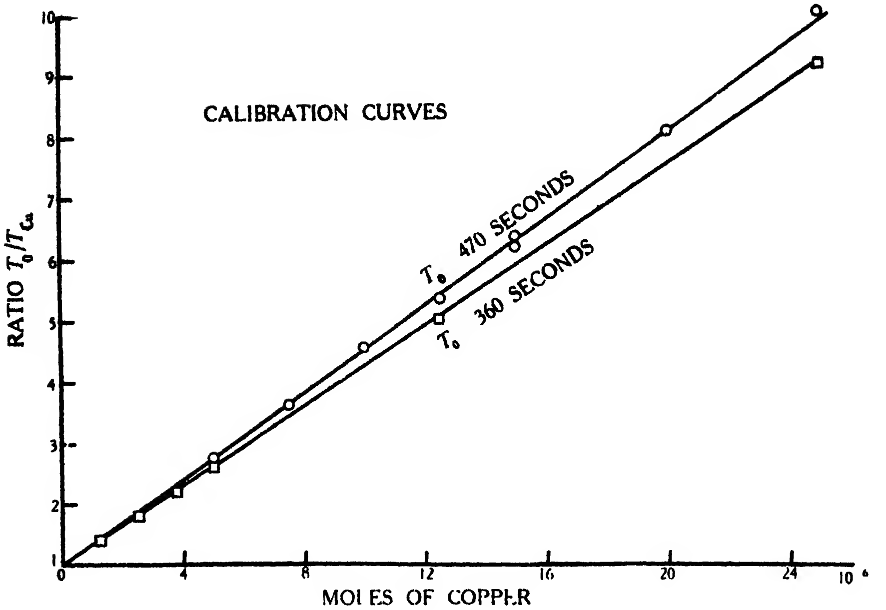

Fig. 2

copper concentration is obtained by employing a factor interpolated between the two known factors. The following table shows the blank time given by the same peroxide solution on different days under identical conditions—

Age of solution (days) .	1	4	5	7	9
Blank time (secs.) ..	371	376	376	382	387

In an actual absorption experiment the blotted and dried sample of cellulose is added to the acid and allowed to become completely wet before the peroxide is added. The standard procedure is then followed, and T_t/T_{cu} is computed. From this, with the aid of the graph or known factor, the amount of copper absorbed by the sample, in 10^{-6} g.moles, is obtained. The result is calculated as 10^{-3} moles of copper per 162 g. of cellulose, an allowance being made for the moisture content of the sample.

Effect of Time on the Copper Absorption

Several experiments were commenced at the same time, 2/40's soda-boiled Sakel yarn being used. The yarn was taken out after varying intervals, and the copper absorption determined. The results of two series of experiments, which are given below, show that absorption is virtually complete after one hour.

Time (hours)	½	1	2	5½	6	21	26
Absorption, 10^{-3} moles per 162 g —							
1st Series	-	—	73·2	—	69·5	68·4	
2nd Series	63·1	65·2	67	65·3	—	—	65·2

The first result in each series being omitted, the mean was taken as 66·8 millimoles of copper absorbed by 162 g. of dry cotton.

Expression of Results as a Ratio

It has been found convenient, and is uniform with the procedure adopted for the soda and baryta absorptions, to divide the observed absorption of any sample by 66·8, the value given above, and so to express the copper absorption

as a ratio relative to that of scoured cotton cellulose. The actual absorptions from the standard solution, and the copper absorption ratios of samples of cotton which have been subjected to various treatments are given in Table IV.

The Absorption of Copper from Cuprammonium Solutions containing Sodium Hydroxide

Hess and Trogus[2] have shown that the addition of sodium hydroxide to cuprammonium hydroxide solution increases the amount of copper that cellulose absorbs from this solution. The theoretical significance of this observation, however, is obscured by their further observation that the addition of sodium hydroxide is also increasing the power of the solution for swelling and dissolving cellulose. It has been shown in this and in the preceding papers that such swelling causes an "activation" of cellulose, and the increased absorption might either be attributed to such an effect or be interpreted as a more specific and fundamental property of the system sodium hydroxide, cuprammonium hydroxide, cellulose. Experiments that have now been made at extreme dilutions of copper indicate that the increase of copper absorption brought about by addition of sodium hydroxide is still marked even when the cellulose remains unswollen. The data are given in Table II.

Experiments on the copper absorbing power of different samples of cellulose have also been done on one of these solutions very dilute in copper but moderately concentrated in soda. The three samples taken absorb widely different amounts of copper, but when the copper and ammonia concentrations are increased up to the values employed by Hess and Trogus, these differences almost disappear (Table III). Hence it may be concluded that

Table II

Absorption of Copper by Scoured Cotton Yarn

Initial concentration of copper, 0·00147 N; of NH_3, 0·25 N; Temp 20° C.

Concentration of sodium hydroxide	0	·075	252	540	·958	·958
Absorption of Cu millimoles per 162 g ...	8·48 8 48	21·0 19·4	29 1, 28 5	43·2 43·2	69·0, 68 0	79·5, 82·9
Final concentration of Cu, equivalents per litre	·00141	·00133	·00127	·00117	·00099	·00131

their observation that different forms of cellulose are equally reactive towards cuprammonium sodium hydroxide is not generally true, but only holds when the solution possesses sufficient swelling power to bring the least reactive up to the level of the most reactive samples of cellulose

Table III

Absorption of Copper from Cuprammonium Sodium Hydroxide

	Copper absorption Millimoles per 162 g	Ratio
Dilute Solution		
Copper, 0·00147 N, NaOH, 0 572 N, NH_3, 0 25 N. Weight of sample, 12 to 25 mg. Vol. of solution, 1,000 c.c.		
Scoured Sakel yarn	54·6, 54·7	1·00
Technically mercerised cloth	75·5, 76·7	1·38, 1·40
Yarn mercerised loose in 25% caustic soda, air dried	160, 160	2·93, 2·93
Solution as used by Hess and Trogus[2]		
Copper, 0·06 N; NaOH, 0 60 N; NH_3, 10 N. Weight of sample, 1 mg. Vol. of solution, 10 c.c.		
Scoured Sakel yarn	540, 546	1·00
Yarn mercerised loose with 25% caustic soda, air dried	581, 571	1·07, 1·05
Cuprammonium rayon	618, 630	1·14, 1·16

Table IV

Copper Absorption Ratios of Various Samples of Cotton Cellulose

Nature and pretreatment of sample	Copper absorption millimoles per mole			Copper ratio	Soda ratio	Baryta ratio
Sakel yarn scoured 1% NaOH for 6 hrs at 20 lb. excess pressure	65·2 69·5		65·2 67·0	Taken as 1·00	1·01	1·02
Technically mercerised cloth	108 108		113 117	1·67	1·62	1·66
Loose scoured cotton pretreated cuprammonium 24 hrs (5·5 g. Cu per litre)	123		142	1·99	1·45	1·36
Scoured Sakel yarn treated loose with 25% NaOH, air dried . ..	187,	178,	169	2·66	2·53	2·66
Above wetted and dried fourteen times at 110° C	145		141	2·14	2·09	2·10
Yarn treated loose with 3*N* NaOH at —7° C	205		205	3·07	2·70	2·79
Cuprammonium rayon	222,	216,	207	3·22	3·20	3·81
Variations of Mercerising Process (all 3 mins at 25° C)						
Mercerised grey and then scoured						
12·5% NaOH No shrinkage .	101		103	1·52	1·41	1·43
25% NaOH No shrinkage ..	116		119	1·76	1·75	1·79
25% NaOH Loose and restretched	122		125	1·85	1·85	1·88
25·5% NaOH. Loose	155		157	2·33	2·33	2·22
Scoured and then mercerised—						
12·5% NaOH No shrinkage .	110		113	1·67	1·60	1·65
25% NaOH No shrinkage ...	159		165	2·42	2·23	2·34
25% NaOH Loose and restretched	157		157	2·35	2·34	2·40
25·5% NaOH Loose	173		174	2·60	2·47	2·61

The Copper Absorption Ratios Characteristic of Various Pretreated Samples of Cotton

Since it has been found in the course of the work described in the two preceding papers that the soda and baryta absorption ratios of most cellulose samples do not, even over a wide range, differ markedly from each other, it is natural to inquire whether the same rough agreement holds for the copper absorption ratio. The data given in Table IV show that this is so, but that cotton pretreated with cuprammonium sufficiently concentrated to cause great swelling is an exception. This sample showed a markedly greater increase of activation towards the dilute cuprammonium than towards the simple alkalis. The dependence of the activation ratios on the alkali concentration, and on the stretching and other conditions of mercerisation, is discussed in the preceding papers.

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24—SOME STUDIES OF THE YOLK IN NEW ZEALAND WOOL
I—THE EFFECT OF SHEEP COVERS ON YOLK PRODUCTION

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(This work has been carried out with the aid of a grant from the Department of Scientific and Industrial Research New Zealand.)

Yolk, or wool grease, consists of the products of the sebaceous glands and of the sweat glands of the sheep. Wool follicles do not all possess sweat glands, and the sebaceous glands vary both in number and in size from follicle to follicle[1,2]. This explains, at least in part, the appreciable differences in amount and in composition of the yolk from one fleece to another, apparent to the naked eye, and appreciated by most sheep breeders, who regard a certain type of yolk as the necessary accompaniment of a superior wool.

In the Romney Marsh sheep, predominating in the North Island of New Zealand, light coloured and liquid yolk which flows to the tip of the wool is supposed to indicate a uniformly grown fibre possessing strength and the minimum amount of "wasty" tip Fleeces in which the yolk is yellow, solid and concentrated in zones, frequently have several inches of wool at the tips poorly supplied with yolk. These tips are usually brittle and reduce the value of the wool.

In the light of recent work by Winson[3] there would seem to be some foundation for the view that yolk influences the character of the wool fibre. This influence might operate in several ways. The products of the sebaceous glands and sweat glands may have some influence on the fibre while still within the follicle. The penetration of liquids into the capillary cavities of the wool fibre has been shown by Speakman to influence the pliability and elasticity of the fibre[4], and there is the possibility that yolk functions in a similar manner, at any rate so far as the microscopically visible pores, observed by Mark[5] in thoroughly degreased fibres, are concerned. There is a popular belief that the yolk nourishes the fibre. Finally the yolk may simply have a protective function, serving to prevent weathering and deterioration of the fibre after it has emerged from the follicle. Whatever may be the true relationship between yolk and fibre it would seem that, empirically at least, a plentiful supply of mobile yolk is to be desired, if only as an indication of the good health of sheep.

As a result of the wide-spread interest among wool growers in the subject of yolk as related to sheep management on the one hand and to wool quality on the other, work was commenced in May 1929 at this college to endeavour to establish some definite information regarding local breeds and conditions. Before such questions as the effect of feeding and other factors on yolk could be investigated, it was necessary to evolve a method of measuring the yolk produced by the sheep's skin.

A considerable proportion of the yolk is liable to be leached out of the fleece by the action of rain, the amount of leaching depending on a number of variable factors such as rainfall, type of fleece, and stage of growth of the fleece. Thus, in order to make comparisons of the total yolk produced by the skin as distinct from the yolk retained in the fleece, it was necessary to devise some means of preventing loss of yolk.

The housing of sheep is not practised in this country, so that there are no facilities for sheltering large numbers of sheep from the weather. The provision of waterproof covers similar to those used on other domestic

animals and frequently on sheep for the show ring, suggested itself as an alternative method of protecting the fleece from the rain.

After some preliminary trials, a suitable cover, protecting the back and sides of the animal, was designed. The object of the experimental work recorded in this paper was to discover whether putting covers on the sheep affected the glandular secretions, e.g., by preventing ventilation or causing irritation and perhaps overheating of the skin, with modified yolk production.

METHODS OF ESTIMATING SUINT AND YOLK PRODUCTION

Several methods of obtaining the clean yield of raw wool, some of them involving separation into wool-fat, suint and dirt, have been described[6,7,8,9].

For the work now described the method had to be capable of dealing with large numbers of samples without demanding continuous attention. A method fulfilling these requirements and at the same time giving reasonable accuracy has been developed. The essential feature of this method is the application of Soxhlet extraction to the estimation of the water-soluble constituents. It is interesting to note that the procedure is almost identical with that recently described by Bonsma[10].

The method in use at this laboratory is as follows -

A sample of the raw wool weighing about 20 grams is weighed in a tared air-tight vessel.* The sample is loosely arranged in the vessel which is placed in an oven at 105° C and dried to constant weight. Sixteen hours is found to be sufficient time for the purpose. At the end of this time the vessel is closed while still in the oven, cooled in a desiccator and weighed.

The dry greasy sample is then carefully transferred to an extraction thimble (43 mm. × 123 mm.), care being taken not to pack the wool too tightly, and extracted vigorously with dry ether in a Soxhlet extractor for six hours. After removing the ether from the wool in the thimble, the sample is extracted with water in a Soxhlet extractor for twelve hours, the flasks being immersed to a depth of 1 cm. in an oilbath at 150° C. The battery of extractors is surrounded by a jacket to minimise condensation in the side tubes. The water extract is then evaporated to dryness in a small weighed porcelain dish on a water-bath, dried to constant weight in the oven, cooled in a desiccator and weighed. Three hours drying at 105° C. is found to be sufficient.

The extracted sample is then removed from the thimble, rinsed first in warm water, then in warm soapy water, and finally again in plenty of warm water, any foreign matter being picked out.

After air drying, the clean sample is transferred to the air-tight vessel, dried at 105° C. and weighed. This method of removing dirt is adopted, since teasing out the fibres as suggested by Marston[11] and Bonsma[10] is too slow for routine work and is difficult to carry out without some loss of soil. The weight of soil, seeds and other foreign matter is obtained by difference. Figures obtained from samples of Romney wool in which the dirt was estimated by teasing out the dry fibres are given in Table I.

* A suitable vessel for the purpose is a pint fruit-preserving jar closed with a spring clip, the pressure of which on a rubber ring seals the joint. Such a jar is easily and quickly closed in a confined space and at a high temperature.

Table I

Sample	Moisture	Ether Extract	Water Extract	Soil, etc.	Clean Fibre	Total Percentage
	14·4	6·4	5·7	4·5	68·8	99·8
2'	14·6	8·5	8·4	4·5	63·8	99·8
: a	16·1	4·1	7·2	2·5	69·8	99·7
: b	16·7	4·3	7·3	—	—	—

EXPERIMENTAL DETAILS

At the end of January 1930, forty sheep were selected from 250 ewe hoggets of the College Romney Marsh flock. These animals were selected as well grown and uniform sheep possessing the same type of fine wool (48's count). They had been shorn at the end of October 1929 and had since grown about two inches of wool.

The sheep were ear-tagged and a sample of wool was taken from the middle of the left side (over the last rib) of each animal by means of the shearing machine. The sheep were then dipped as usual to avoid parasites, it being assumed that only a negligible quantity of dip fluid would adhere to the short length of wool on the newly shorn area. It was decided to work on wool from the side, as work in America on Rambouillet sheep[8] has shown that the wool from the side is intermediate in the amount of yolk which it contains between the extremes afforded by other parts of the fleece, and approaches most closely to the average of the whole fleece in this respect.

Twenty of these forty sheep were chosen at random and were fitted with light waterproof covers. Both groups were then run together on paddocks adjacent to the wool shed into which they were driven whenever rain threatened, and, if necessary, at nightfall. As there was but little rain in the three months during which the experiment was carried out, the sheep were seldom in the wool shed for more than a few hours at a time. The wool shed used to shelter the sheep is a large well ventilated and well lighted building divided into pens. The grating floor was covered with straw bedding which was frequently changed. Each pen was supplied with abundance of water, hay, and turnips.

This treatment was continued for ninety-six days, the covers being adjusted as became necessary. At the end of this period a sample of wool was taken from each sheep from the area originally sampled. None of the sheep were exposed to rain during the period of the experiment, so that no loss of yolk occurred. Since they were all treated alike any difference between the two groups should be due entirely to the effect of the covers on the covered group. There was no apparent discomfort caused by the covers when properly adjusted, and all the sheep throve during the experiment, being given frequent changes of pasture, and otherwise treated in the normal manner.

RESULTS

So far no method has been devised for measuring the total amount of yolk produced by the skin of the sheep, and it has been usual to express the yolk and its constituents as percentages of the raw wool. There are several obvious objections to this method, e.g., varying moisture content of the raw wool samples, and variable contamination with soil, dung, and other extraneous matters.

To eliminate any effect on the yolk figure due to these external factors, the method adopted here is to express the ether-soluble extract and water-soluble extract as percentages of the dry clean fibre.

Table II gives the results at the initial and final samplings. In order to compare the results, the number of samples, the arithmetic mean, the

Table II
Ether Extract and Water Extract at Initial and Final Samplings expressed as Percentages of Dry Clean Fibre

Sheep Uncovered during Experiment					Sheep Covered during Experiment				
	Initial Sampling		Final Sampling			Initial Sampling		Final Sampling	
No	Ether Extract	Water Extract	Ether Extract	Water Extract	No	Ether Extract	Water Extract	Ether Extract	Water Extract
838	9·1	12·0	13·2	24·6	837	10·4	12·8	13·7	22·0
839	13·1		15·9	17·4	841	8·5	8·3	8·0	15·4
840	9·6	—	12·8	29·2	845	9·0	8·8	12·7	16·6
842	7·3	6·2	—	18·9	846	9·2	10·0	12·1	19·3
843	6·3	9·8	8·4	18·8	848	9·9	7·4	9·1	12·9
844	6·6	7·4	8·2	9·9	851	7·2	7·1	8·3	17·0
847	9·9	10·8	11·4	16·5	852	9·5	9·0	12·3	18·4
849	9·2	11·0	10·8	19·3	853	4·8	9·5	9·1	15·6
850	5·6	9·2	10·1	21·4	855	6·3	8·5	7·0	14·6
854	7·7	8·1	12·8	21·4	859	7·0	10·0	8·0	16·3
856	7·6	4·2	10·2	12·3	860	11·9	9·4	13·9	21·6
857	8·0	13·0	9·5	18·6	861	7·7	9·5	8·1	16·9
858	7·2	–	12·3	13·8	862	7·3	10·0	5·7	16·2
863	9·3	11·3	10·5	20·2	864	8·6	12·7	10·9	13·0
865	7·7	8·9	9·2	22·5	868	6·8		8·6	14·5
866	7·4	11·5	8·3	18·6	869	9·0	10·2	10·7	23·6
867	7·0	6·7	9·0	16·0	870	9·9	8·3	11·9	14·7
872	8·0	13·4	9·1	20·1	871	6·1		14·2	18·2
873	6·7	7·8	7·8	23·7	875	8·4	7·4	12·9	24·3
874	7·4		8·5	10·3	482	9·0	12·6	7·7	34·6

Table III
Summary of Data in Table II

Sampling		Ether Extract		Water Extract	
		Uncovered Sheep	Covered Sheep	Uncovered Sheep	Covered Sheep
I	n	20	20	16	18
	M	8·0	8·3	9·5	9·5
	σ	1·7	1·7	2·7	1·9
	σ_M	0·39	0·39	0·70	0·46
II	n	19	20	20	20
	M	10·4	10·2	18·7	18·3
	σ	2·2	2·6	4·8	5·1
	σ_M	0·52	0·60	1·10	1·17

Where— n = Number of samples.
M = Arithmetic mean.
σ = Standard deviation.

$$= \sqrt{\frac{\Sigma x^2}{n - 1}} \qquad x = \text{deviation from M}$$

σ_M = Standard error of mean.

$$= \frac{\sigma}{\sqrt{n - 1}}$$

standard deviation, and the standard error of the mean for each class in these two tables are given in Table III.

DISCUSSION

From Table III it is seen that at the initial sampling there is no significant difference either in ether extract or in water extract between the values for the sheep chosen to be covered and those not to be covered, so that the two groups were initially comparable. The same is true at the final sampling. Though there was a considerable increase in the amount of ether extract during the experiment and the water extract was almost double, yet the increases are of the same order for the covered sheep as for the uncovered. This experiment has failed to detect any influence of sheep covers on yolk production. If such an influence exists it is quite insignificant compared with the normal variations between individuals.

It thus appears that the provision of waterproof covers for sheep is a suitable method of protecting the fleece from the weather for experimental purposes. This method will enable further work to be extended to investigations into the effect of climate, soil, and feeding on yolk production, and the relationship between yolk characteristics and wool type.

SUMMARY

(1) A routine method for estimating the constituents of greasy wool is described.

(2) An experiment is described in which the effect of light waterproof sheep covers on the production of yolk by the skin is investigated.

(3) The conclusion is drawn that for the New Zealand Romney Marsh sheep under local climatic conditions the effect of sheep covers on yolk production is quite insignificant compared with the normal variations between individual animals.

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25—THE SULPHUR CONTENT OF SOME NEW ZEALAND WOOLS

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In a previous paper[1] the author described the collection of the New Zealand fleeces sent to Torridon for a trade report and a laboratory examination. For the purpose of examination of the sulphur content of some of these wools, fleeces were selected in pairs from the various lots so that the fleeces in each pair were from sheep of the same age and sex, and which had been produced under similar conditions. Each individual pair, with the exception of the two lots numbered 18 which came from the same flock, came from flocks in different parts of New Zealand with different soil and climatic conditions. Thus comparable results were obtainable. According to the trade opinion obtained, one fleece of each pair was classified as a good spinning wool and the other as being not so good.

The same shoulder sample was used in these experiments as was used in the experiments described in the previous paper[1], and the sub-samples required for the analyses were obtained by taking a random staple from each of the 16 zones. The sub-samples so obtained were thoroughly cleansed by two washings in hot benzene, one washing in a 0·1% Saponin solution and several changes of distilled water. After drying, the wool was combed on two hand cards to permit of better conditioning and sampling and was left for at least twenty-four hours in a room kept at a fairly constant humidity. Samples were then taken for moisture determination by the method described by Barritt and King[2] and for sulphur content by the method described by Rimington[3]. The results of the analyses are shown in the accompanying table. Each result is the average of three or more determinations on the one sample and the Standard Error of the result is given.

It will be seen from the Table that, in every case except one, the better spinning wool of each pair has a higher sulphur content than the lower class wool, and that in the case of the exception there is no significant difference. For each pair of fleeces the sulphur content is also in inverse proportion to the Coefficient of Variation and the contour figure, i.e., the wool that by laboratory examination should theoretically be the better spinning wool, has the higher sulphur content. It would, therefore, appear from this work that there is a correlation between the spinning properties and the sulphur content of a wool. Admittedly there are not many analyses in this set, and so a good deal more work will be necessary before any definite statement can be made. The author hopes to continue the work in New Zealand where duplicate samples are available.

These results are probably unique in that it is the first case in which there has been available a series of wools of known history grown under similar conditions, so that one sample was selected for its good spinning properties the other being indifferent in this respect, while other factors and characteristics are as closely comparable as possible. With the exception of the analyses carried out by Bonsma[4], most of the other sulphur analyses that have been made have been on wools of which very little has been known of the previous history. It is only by a study under the conditions described above, with probably a little more control over conditions, that any general conclusion can be arrived at. It is also possible that the relationship between

Table I

Pair No	Good Processing Wool according to Trade opinion: Description of Sample	Sulphur %	Coefficient of Variation %	Contour A B Ratio	Fair Processing Wool according to Trade opinion: Description of Sample	Sulphur %	Coefficient of Variation %	Contour A B Ratio	Remarks
I	Tag I	3.16 ± 0.026	31.0	1.185	Tag II	3.16 ± 0.029	45.0	1.203	Two Romney ewe wools from a stud flock in the Masterton district (North Island)
II	24A	3.17 ± 0.033	40.2	1.155	24B	2.97 ± 0.023	45.6	1.246	Two Romney ewe hogget wools from a stud flock in the Invercargil district (South Island)
III	26A	3.21 ± 0.032	40.7	1.219	26C	3.11 ± 0.015	44.6	1.234	Two stud Corriedale ewe hogget wools from the Palmerston South district (South Island)
IV	18C	3.02 ± 0.009	33.4	1.156	18B	3.04 ± 0.007	44.6	1.234	Two stud Corriedale ewe hogget wools from the Rangiora district (South Island)
V	18D	3.18 ± 0.012	X	X	18A	3.07 ± 0.018	38.9	1.273	Remarks as for 18C and 18B

X = not determined

sulphur content and spinning quality may more clearly emerge in the case of crossbred wools than in Merinos because the Merino is a more standardised type while in the crossbred desirable or undesirable characteristics are more likely to be met with.

It is of interest to note that the figures quoted in Table I of Bonsma's paper[4] lend a certain amount of weight to the theory that there is a correlation between sulphur content and spinning qualities of wool. Of the fifteen wools quoted in this Table, twelve have either a "very good" or a "good" soft handle, and in nearly every case the sulphur percentage is over 3·6 per cent. The other three wools have only a "fairly good" or "poor" handle and the average sulphur percentage of these wools is as low as about 3·2 per cent. "Handle" is a term which is admittedly difficult to define, but there appears to be some relationship between the handle of a wool and the manner in which it spins.

Another point of interest is the low percentage of sulphur in the Romney wools compared with that of Merino wools. Barritt and King[2] have shown that kemp and medullated fibres are low in sulphur content compared with normal fibres and this fact may help to account for the tendency of Romney wool to produce medullated fibres when placed under poor nutritional and breeding conditions. It may be argued that the Romney produces a greater bulk of wool through which the sulphur has to be distributed than does the Merino, but on the other hand, it has to be remembered that the Romney probably consumes considerably more food than the Merino. Also as a general rule, the quality and, therefore, the probable protein-sulphur content of the class of pasture grazed by a Romney is considerably better than that available for the Merino. Another fact arises in this connection which may have some influence on the question of Thickened Tip in Romney wool. In Dr. Dry's report[5] on differential shearing with regard to Thickened Tip, it is stated that the work provides a definite case of the influence of environmental conditions upon medullation. It is conceivable that the question of the type of food being eaten may have a direct bearing on this question, for if a sheep is shorn during warm weather, when there is a tendency for the pasture to deteriorate, then the sulphur intake may not be sufficient to meet the demands of the wool follicles to produce wool to protect the sheep's skin, and so instead of producing a true wool fibre a medullated fibre may be produced. On the other hand, if a sheep is shorn during cooler weather, when there may be a flush of fresh pasture growth, then the sulphur intake may be sufficient to meet the demands for wool growth.

It is possible, therefore, that there is a combination of genetic, biological, and nutritional factors responsible for the production of medullated fibres in Romney wool.

If further work shows that there is a definite correlation between the sulphur content and the spinning properties of a wool, it will open up a new avenue for the improvement of crossbred wool. Bonsma in his paper[4] points out that the sulphur content of wool is probably an inheritable characteristic which may be modified by certain circumstances, particularly feed change. If this be so, then by selecting towards high sulphur content and by attention to the food of the sheep, it is reasonable to expect that a better class spinning wool will be produced.

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26—A PRELIMINARY STUDY ON THE RELATIONSHIP BETWEEN CRIMP AND CONTOUR IN WOOL FIBRES

By S. D. Rossouw, B.Sc.

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(From the Wool Industries Research Association)

Many phases of the subject of crimp in wool have been studied. Barker and Norris (1930) have elaborated a mathematical theory to explain the formation of crimp in wool. It is also an established fact that a fair relationship exists between the number of crimps per unit length and the fineness or quality of a lock of wool. Hartmann and Pabst (Kronacher), 1930, devised an instrument consisting of a number of toothed plates of different pitch for measuring crimp and thus directly deducing fibre fineness. Duerden (1929) applies this method on a practical scale in South Africa by supplying the wool farmers with plates of different serrations. Hirst and King (1926) in their work on mohair kemp, recorded observations of the rotation of the major axis of the fibre cross-section corresponding to the phase of the crimp.

Barker and Burgess (1928) and many other workers have pointed out the elliptical nature of the wool fibre. Isolated fibres of Chinese sable have been examined in the fibre rotator (Barker and Norris) and it was found that the contour varies considerably along the length of the fibre, and also that the axes of the cross-sectional ellipse do not necessarily lie in the same plane at various positions along the fibre length. In the present investigation the latter phenomemon has been examined in minute detail for parts of fibres which showed very regular crimp, and the results have been correlated with details of the crimp.

Crimp measurements are here based on the number of crimps per 10 cms. of unstretched fibre. The crimps were first counted in the lock, and the number found later confirmed in the isolated fibre. A fibre possessing a very even crimp was selected and placed on a velvet board so that its natural or unstretched length could be measured. This length was noted. The fibre was then placed in the rotator and extended to its natural crimped length, as measured, 2 mms. being allowed for the length of fibre held in the chucks. The fibre was then washed with benzene by means of a delicate brush, examined in detail and the number of crimps checked. The fibre rotator was found to be a very useful instrument for studying crimp characteristics in great detail, expecially when dealing with fine Merino fibres.

The image of the fibre was reflected, by a 45° prism, on to a sheet of millimeter paper on the table, and the distance adjusted to give a magnification of 300 diameters. Goodrich acid seal paint No. 1011 was used to mark the crests of the crimp waves; it was found very suitable as it did not flow, was quick drying, and left a distinct, opaque mark. The paint was applied by means of a single fine bristle whilst the fibre was under a magnification of 300 diameters. It was found that the crest of the wave could be marked fairly exactly in this way, the paint usually covering a length of only about 0·01 cm. along the fibre, or even less.

After marking, the fibre was stretched in the rotator until nearly straight. It was found that most of the crimp disappeared on extension of the fibre, but that a slight residual waviness, easily seen on the projected image, was very difficult to remove and only disappeared when the fibre was under a distinct

tension. As, however, this waviness did not interfere with measurements of diameter, its removal was not attempted. Further, the point at which the crimp disappeared but the waviness remained, was apparently fairly definite, as repeated determinations of this point gave results differing by only 3 per cent.

A lock of Merino shoulder wool, showing a particularly even and regular crimp, was selected. It had about 63 crimps per 10 cms. Ten fibres were selected and examined as described above. Measurements were taken at every 0·2 cm. along its length. The results are given in Table I.

Table I

Fibre No	*Average $AB\times\frac{\pi}{4}$	†Average A/B	Percentage Extension
1	33·6	1·16	31
2	39·3	1·14	40
3	57·1	1·16	40
4	39·8	1·18	39
5	38·3	1·14	38
6	31·4	1·19	33
7	25·3	1·20	24
8	35·2	1·22	37
9	14·0	1·16	37
10	20·9	1·14	38

* A and B represent the major and minor axes of the cross-section of the elliptically-shaped fibre, and the cross-sectional area $\left(AB \times \frac{\pi}{4}\right)$ is expressed in square centimetres $\times 10^{-7}$

† This method does not give a very reliable figure for the circularity ratio

The figures in Table I show clearly that it is impossible to deduce fineness of wool fibres from crimp counts when considering single fibres. All these fibres had approximately the same number of crimps per unit length and yet, according to their cross-sections, they belong to quality classes ranging from 56's to over 90's.

To obtain the cross-sectional area, the width of the image was measured at the same point through a rotation of 180°, at intervals of 30°, and the major and minor axes selected from seven readings. Such determinations were made at intervals of 0·2 cm. along the length of the fibre, and the average cross-sectional area of the whole fibre calculated. In almost all cases these Merino fibres showed a fairly constant cross-sectional area along their length.

The percentage extension, which depended on the type of crimp, gave values mostly round about 37 and 40, although in one case it was only 24. Further investigation is necessary before any conclusions can be drawn.

The next part of the problem to be investigated was the shape of the fibre, and the correlation of this with the crimp. For this purpose a fibre* was measured at the crest of each crimp wave, being rotated through 180° at each of these points and measured at intervals of 30°. The portion of the fibre which was measured appeared to have waves which were very nearly uniplanar, but the plane gradually rotated through an angle of about 90°. The results are given in Table II.

* One of the Merino fibres of Table I.

Table II

No of Crest		Position of Vertical Plane of Wave (rotation)		Position of Minor Axis
6	...	60°	...	60°
7	...	90°	...	90°
8	...	100°	...	90°
9	...	120°	...	150°
10	...	150°	...	150°
11	..	165°	...	150°
12	...	150°	...	150°

To obtain the positions of the minor axis, readings were taken at intervals of 30° through a rotation of 180°, and the angle at which the minimum value was obtained noted. If two minimum readings were found, the mean of the corresponding angles was taken as the position of the minor axis, which was thus indicated to the nearest 15°, except where the cross-section was approximately circular.

The figures in Table II show that, at the crest of the wave, the minor axis of the cross-section lay in the same plane as that in which the fibre was crimped, or, in other words, it was apparently like a bent ribbon. In order to find if this type of bending persisted throughout the fibre its contour was investigated more precisely. Thus, starting from a wave crest, the fibre diameter was measured at intervals of 30 rotation at every 0·025 cm. along a few cms. of its length. Three fibres were measured in this way and all gave similar results. A typical series of measurements is given in Table III.

Table III

Distance from 1st Crest in cms.	Width of Image at the following angles— 0°	30°	60°	90°	120°	150°	180°
0·000	85	85	80	80	80	80	85
0·025	85	75	$\boxed{70}$	75	85	90	85
0·050	85	85	80	75	$\boxed{70}$	75	85
0·075	65	75	90	90	85	70	$\boxed{65}$
0·100	75	80	80	80	70	$\boxed{70}$	70
0·125	80	75	65	65	75	80	80
0·150	65	65	80	90	80	70	$\boxed{60}$
0·175	85	80	70	$\boxed{65}$	70	80	90
0·200	80	75	$\boxed{70}$	75	80	85	80
0·225	80	70	$\boxed{65}$	75	80	85	80
0·250	80	80	75	70	$\boxed{65}$	70	80

The approximate position of the minor axis is indicated by the enclosed numerals.

The figures given in Table III are for a length of fibre containing rather more than one complete crimp wave. They clearly show to what extent the plane or the minor axis of the elliptical cross-section of the fibre is rotated in one crimp wave. It apparently follows an oscillatory path between certain angles, along the length of the fibre. However, the possibilities of conformation of twist other than those which are shown in the table are many. For instance, in the case of the measurements at the points at

0·125 cm. and 0·150 cm. it is possible that instead of reversing to 180° the twist may have continued to, say, – 10°. Or again, the twist in the fibre may be in the form of a continuous spiral, although it appears much more probable that its orientation oscillates between certain angles.

The above results agree well with some unpublished data obtained by Claassens who also observed this irregularity in the angle and direction of twist, and Danforth (1925) also states that human hair shows "twisting of the individual hairs on their own axis."

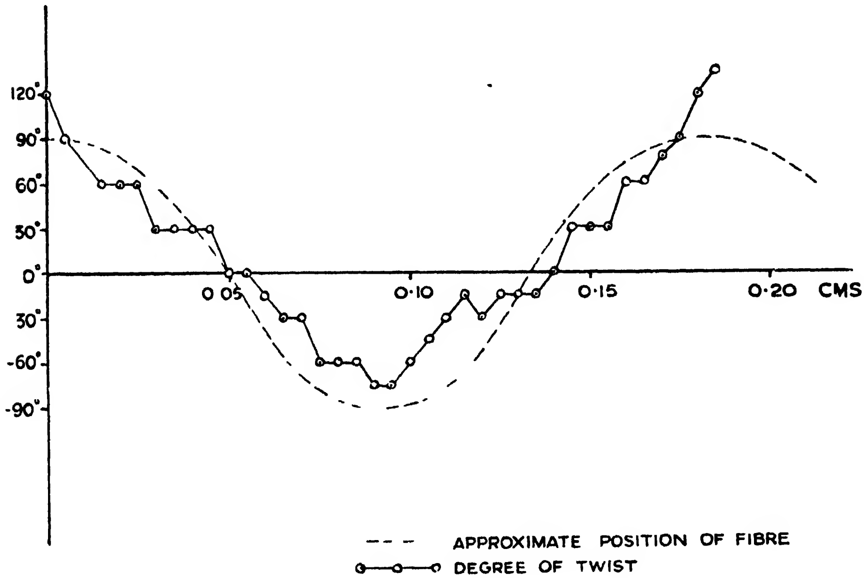

FIG. 1

However, it is quite clear from the results of Table III that measurements at 0·025 cm. intervals are insufficient for establishing the orientation of the contour of fine Merino fibres Measurements were therefore taken at intervals of 0·005 cm The results are given in Table IV, where the position of the minor axis of the cross-sectional area is again indicated by the enclosed numerals. Had it been possible to measure the fibre through a rotation of 360° instead of only 180°, the curve joining the square would, of course, have been continuous.

The longitudinal movement of the fibre over such distances was not difficult, being accomplished by giving the carriage of the rotator a number of slight taps with a pencil while watching the projected image of the fibre. Movements of 30 mms. of the image represent a movement of only 0·01 cm. of the length of the fibre and by utilising small specks of particles of dust on the fibre, as landmarks, it was easy to measure a movement of 30 mms. of the image which could thus be adjusted to the nearest millimetre, representing $\frac{1}{300}$th part of a millimetre of fibre length.

Table IV

Position on Fibre in cms.	Diameter of Image in mm 0°	30°	60°	90°	120°	150°	180°
1·240	90	95	90	75	$\boxed{70}$	80	90
1·245	90	85	75	$\boxed{70}$	75	90	90
1·250	95	85	$\boxed{65}$	70	85	95	95
1·255	95	80	$\boxed{65}$	70	85	95	100
1·260	85	80	$\boxed{70}$	80	85	90	85
1·265	80	$\boxed{70}$	75	80	90	85	80
1·270	80	$\boxed{70}$	75	80	90	85	75
1·275	80	$\boxed{70}$	75	80	90	80	80
1·280	75	$\boxed{70}$	80	80	85	80	75
1·285	$\boxed{70}$	75	80	90	85	80	$\boxed{70}$
1·290	$\boxed{70}$	75	85	90	80	75	$\boxed{70}$
1·295	70	80	85	85	80	70	70
1·300	75	85	90	85	85	$\boxed{70}$	75
1·305	80	90	85	80	75	$\boxed{70}$	80
1·310	80	90	80	75	$\boxed{70}$	75	80
1·315	80	90	80	75	$\boxed{70}$	75	80
1·320	80	90	85	75	$\boxed{70}$	75	80
1·325	85	90	80	70	70	80	85
1·330	85	90	80	70	70	75	85
1·335	85	85	80	70	$\boxed{65}$	70	80
1·340	80	85	85	80	70	70	80
1·345	70	80	85	80	70	$\boxed{65}$	70
1·350	75	80	85	80	75	70	70
1·355	75	85	90	80	75	$\boxed{65}$	75
1·360	75	85	90	85	75	70	70
1·365	70	80	90	90	80	70	70
1·370	70	75	80	85	80	70	70
1·375	$\boxed{65}$	70	80	80	80	75	$\boxed{65}$
1·380	70	$\boxed{70}$	70	80	80	70	70
1·385	70	$\boxed{65}$	70	75	80	80	70
1·390	75	$\boxed{65}$	70	80	80	80	75
1·395	75	70	$\boxed{65}$	75	80	80	75
1·400	80	70	$\boxed{60}$	65	80	90	80
1·405	85	75	60	60	70	80	85
1·410	80	80	70	$\boxed{65}$	70	80	85
1·415	85	85	75	65	$\boxed{60}$	70	85
1·420	80	80	80	70	60	60	75

These later results throw considerable light upon the actual behaviour of the twist. The natural fibre is found to have a gradual twist in one direction, progressively increasing to 180°, and after this the direction of the twist is reversed and gradually assumes the value of 180° in the opposite direction. The fibre used showed uniplanar crimp with very little rotation of the plane of the crimp. The length of the fibre represented in the table is one wave length of crimp. Figure 1 illustrates this table, the abscissa representing the distance along the fibre and the ordinates the angle of rotation.

It will be noticed that the reversal of the direction of twist coincides with the trough of the wave. Further measurements along the fibre showed another reversal in the direction of twist, coinciding with the crest of the next wave. Another fibre from the same lock was selected and measured in the same way, but seven waves were measured instead of one. Before stretching to remove undulations, the crests were carefully marked.

A continuous curve for seven successive waves was plotted for this fibre. Although this graph did not show such regular curves as that of the previous fibre, the same general inference still persisted throughout the length measured. That is, the approximate position of the crests and troughs always coincided with a reversal of the direction of twist in the fibre.

According to Danforth a similar phenomenon occurs in human hair. He states that "generally the twisting consists of a series of half turns so that one side of the hair is alternately towards the observer and away from him."

The seven parts of the curve described above were then superimposed, resulting in the graph given in Figure 2.

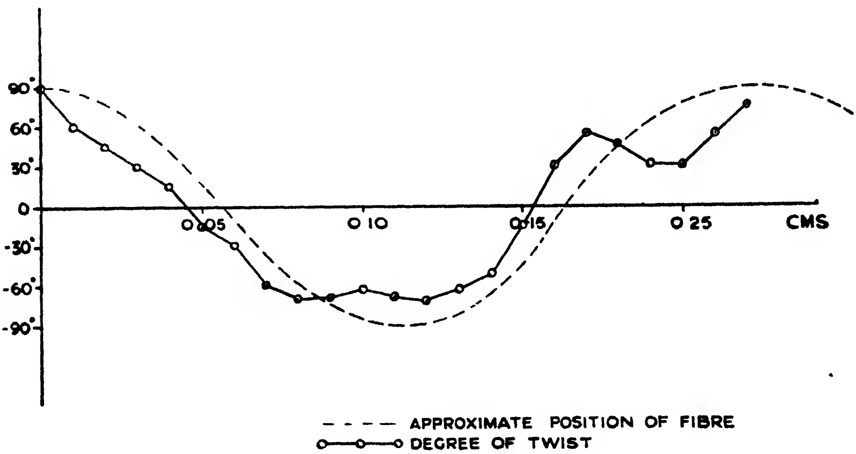

FIG 2

The elementary wave in the second half of this curve is not without significance, for all the component curves showed at least a tendency to possess such a wave at approximately the same position. An examination of the crimp of this fibre through a lens showed a peculiar "twist" in the fibre, a short distance in front of the crests. The trough did not show this, as was observed when the fibre was rotated through 180°.

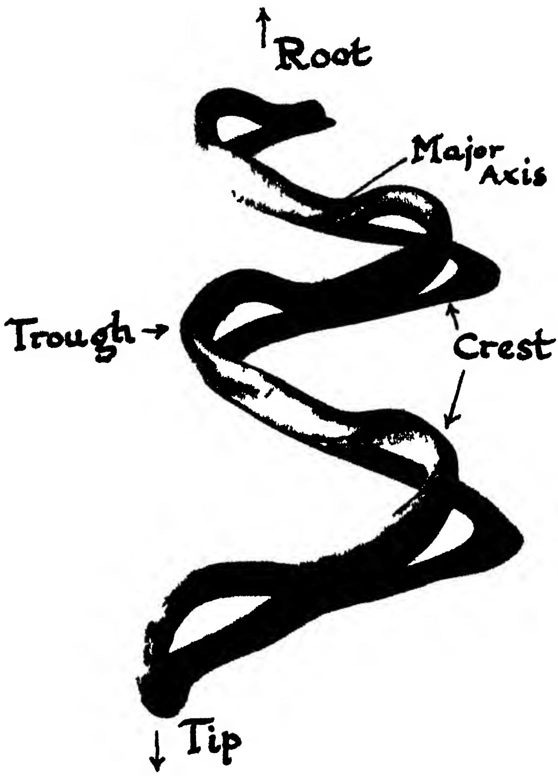

PLATE I

The next fibre to be examined was a New Zealand Romney*. A suitable fibre was selected from a lock showing a particularly even crimp. This fibre had 15 crimps per 10 cms. (unstretched length) in the length examined. After being cleaned with benzene it was carefully marked at the crests in the part to be examined, and subsequently a micro-examination of the whole fibre was made while in the rotator.

Although the crimp appeared to be uniplanar, a close examination showed it to lie along a well defined, narrow longitudinal strip, the surface of a cylinder of about 3 cms. in diameter. Although, however, the general shape of the crimp appeared thus to be a cylindrical strip parallel to the axis of the cylinder, in the actual detail it was much more complicated. Thus examining the fibre from root to tip as it lies on the concave surface of the cylinder, the wave appears to be of the following shape. Starting from the axis of the crimp wave up to the crest it lies on the cylindrical surface; here it lifts out into the cylinder and gradually meets the surface again about half-way towards the axis, remaining in the surface until it reaches the turning point in the trough. It is then bent slightly into the cylinder as at the crest, meeting the surface again about half-way towards the axis. These factors are all illustrated in the model in Plate I.

This finding agrees very well with one of the diagrammatic representations (about 300 diameters) of crimped wool fibres, as depicted by W. von Nathusius (1866). From the diagram, however, it appears that he did not observe any rotation of the axes of the cross-sectional ellipse.

The twist of the plane of the minor axis of this Romney fibre was then examined in the same way as for the Merino fibres. With such a thick fibre it was found sufficient to make measurements at intervals of 0·04 cm. The shape of the curve obtained can be seen in Fig. 3.

Three continuous waves are represented in this curve and it will be noted that they are very similar to those previously obtained for Merino fibres. Further, on stretching, the Romney fibre gave the same percentage extension as most of the Merino fibres, viz., 39 per cent. Apparently, therefore, both kinds of fibre exhibit a similar type of crimp.

In order to examine still another kind of fibre, a N.Z. Corriedale wool† was chosen. The lock showed a crimp, similar to, though slightly smaller than, the Romney. Measurements were made at intervals of 0·01 cm. and the results are presented in Fig. 4. As will be seen, the rotation of the ellipse agrees well with that found for the other fibres examined.

In all cases it is clearly suggested that a change in the direction of twist in the fibre corresponds with a crest or trough of a crimp wave and that this periodicity continues throughout the length of the fibre. Danforth, in his treatise on "Hair," makes the following important comparable observations about human hair; that the length of hair that is involved in a twist may vary from less than a millimetre to several millimetres, also that when these twists, or half turns, involve only a short distance of the hair shaft, and especially when two or more twists occur close together, the hair tends to change its direction in a way that gives it a peculiar frizzly character. It is not surprising, therefore, that with a crimped wool fibre these reversals of twist are similarly found to occur close together. Apparently this twist has been noted even in the follicle.

* This was N.Z. Romney Hogget No. 1. See Table I of Norris (1931)

† This was N.Z. Corriedale No 1. See Table I of Norris (1931).

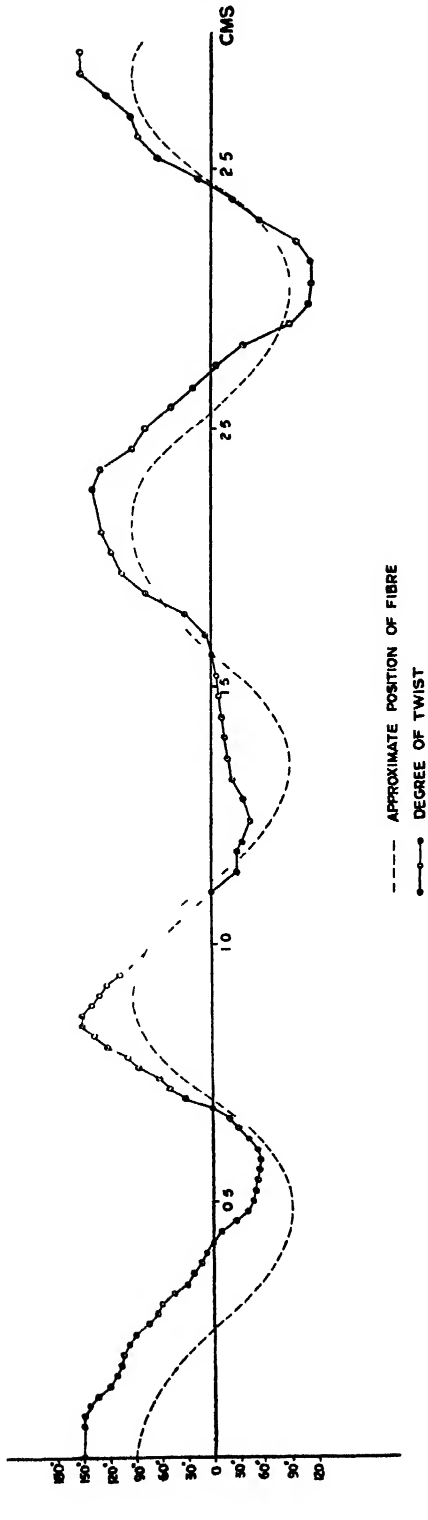
CMS
0 5
10
15
25
2 5
APPROXIMATE POSITION OF FIBRE
DEGREE OF TWIST
180
150
120
90
60
30
0
30
60
90
120

FIG 3

The peculiar behaviour of the twist in a wool fibre, as here described, is not without significance. It has been suggested that the Henle and Huxley layers of the follicle together form the keratinised sheath of the developing fibre, this sheath thus functioning as a mould. Accurately to determine the shape of the follicle, and to note how it conforms to the shape of these wool fibres suggests itself, therefore, as the next step in the investigation. This, and further histo-chemical studies, should ultimately reveal the mechanism involved in the production of crimp and twist in the wool fibre.

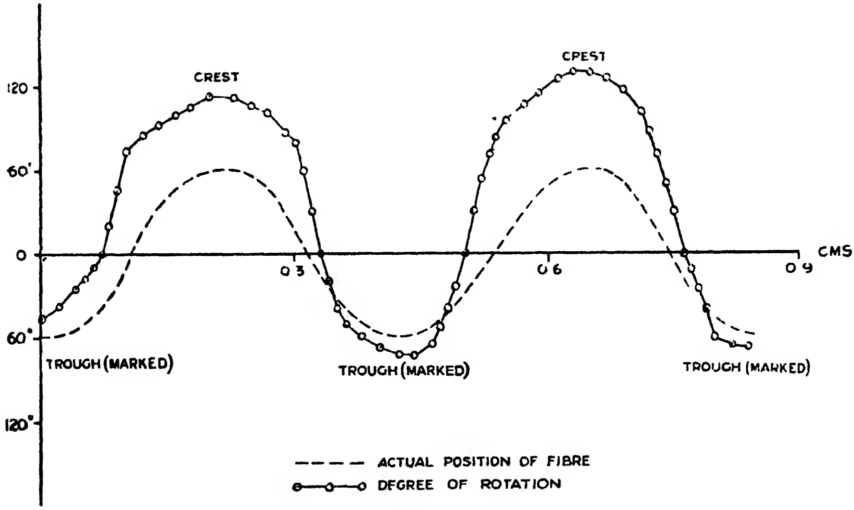

FIG. 1

SUMMARY

(1) Some fibres of Merino and Romney wool have been examined by means of the fibre rotator to determine the path followed by the minor axis of the cross-sectional ellipse along the length of the fibre.

(2) It was found that in order to define this path at all accurately, it was necessary to measure the fibre at very close intervals along its length (0·005 cm. to 0·040 cm depending on the thickness of the fibre).

(3) In every case it was found that a reversal of the angular rotation of the plane of the minor axis which oscillated through approximately 180°, corresponded with a crest or trough of a crimp wave.

(4) The formation of crimp waves in a Romney fibre was examined in detail and a wax model (Plate I) of part of the fibre constructed, which shows both the exact form of the crimp waves and the path followed by the major axis along the fibre length.

ACKNOWLEDGMENTS

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appreciation of the helpful advice and criticism accorded to him by Miss M H Norris and other members of the staff

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THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

27—SOME FURTHER NOTES ON THE PHOTOELECTRIC METHOD OF MEASURING YARN LEVELNESS

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(Wool Industries Research Association)

Since the publication of the details of the photoelectric yarn levelness tester in this *Journal* (Vol. XIX, 1928, T405–T414), a number of improvements have been made, which it is thought might be of general interest. The instrument has been in almost continuous use for testing and grading all types of commercial and experimental yarns, and alterations have made it adaptable for use with certain types of rovings.

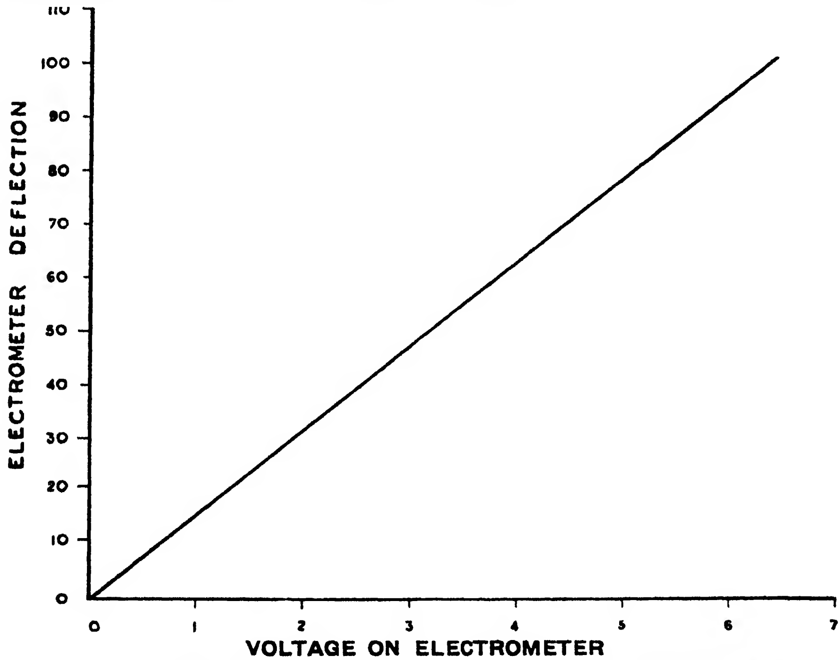

FIG. 1 Relation between Electrometer Deflection and Applied Voltage.

The following is a more complete account of the experimental and theoretical justification for using the photoelectric cell-Lindemann electrometer system for the continuous recording of yarn diameters.

(1) The Relationship between the Potential applied to the Electrometer Needle and the corresponding Deflection.

(N.B.—In these and most of the subsequent experiments the circle of illumination on the recorder screen stretched from 90 to 210 mm., giving a working range of from 100 to 200 mm., i.e. 10 cm.)

The plate potentials were adjusted so that the needle image was approximately in the middle of the field, and by means of a potentiometer in series

with the high resistance R, a small potential was applied to the needle so that its image was brought to the 100 mm. mark at the beginning of the scale. Gradually increasing potentials of opposite sign were then applied to the needle until the maximum deflection was reached on the other side of the scale, readings being taken at regular intervals. The results are given in Table I, and are reproduced graphically in Fig. 1. The curve reveals a linear relationship between the applied voltage V and the deflection D, showing that over the small range which is being used, the field is quite uniform. The figures give D=15·8 V.

Table I

Plate potentials +20·38 volts
−14·55 volts

Zero with *no* applied plate potential +153 mm
Zero *with* applied potential −140·5 mm

V=Needle potential in volts, reckoning Zero at 100 mm ...	0	0·4	0·8	1·2	1·6	2·0	2·4	2·8	3·2
D=Deflection in mm ...	0	6·8	13	19·8	26	32	38	44·5	51
V=Needle potential in volts, reckoning Zero at 100 mm ...	3·6	4·0	4·4	4·8	5·2	5·6	6·0	6·4	—
D=Deflection in mm	57	63·2	69·5	75·8	82	88	94·2	100·8	—

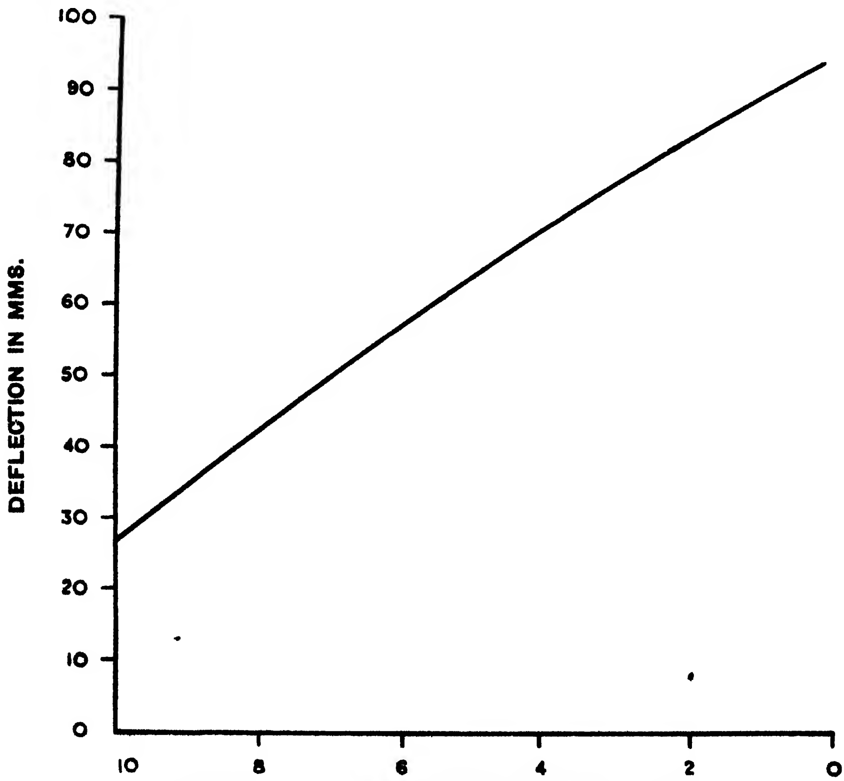

FIG 2. Curve showing Degree of Uniformity of Illumination over the Slit.

(2) The Degree of Uniformity of Illumination over the Slit.

The slit was first of all mounted under a travelling microscope and the opening measured for different settings of the micrometer head adjustment, the results being recorded in Table II.

Then starting with the slit fully opened and the cell voltage adjusted to give a full scale deflection, the slit was closed by successive double whole turns of the micrometer head, and readings were taken of the corresponding electrometer deflections. These results are also given in Table II, and are reproduced graphically in Fig. 2. The curve reveals the fact that the illumination is not quite uniform over the whole area, being more intense in the centre and tailing off towards the sides. If, however, the slit is never used with an opening greater than about 0·25 cm. (four turns), the relation between the deflection and the slit width is sensibly linear, and the illumination can then be taken, for all practical purposes, to be uniform over the slit.

Table II

Plate potentials + 20·38 volts
− 14·55 volts

No. of turns on micrometer head	0	1	2	3	4	5	6	7	8	9	10
Slit width in cms ...	0·362	0·334	0·307	0·279	0·251	0·224	0·196	0·168	0·140	0·113	0·085
Deflection in mm ...	94	—	82	—	70	—	57	—	43	—	27

(3) The Relationship between the Amount of Light Transmitted through the Slit and the Electrometer Deflection.

Two aluminium sector discs were mounted in such a way that they could be moved coaxially one over the other. The discs were so placed that when they were rotating the beam of light falling on the photoelectric cell was alternately intercepted and transmitted. It has been shown by Hyde[1] that the transmission ratio of a disc of this kind, if due precaution be taken to avoid stray light, is accurately the same as the ratio of the total angle open to the total angle closed. By rotating the discs one over the other, various ratios of light to dark from 2 to 0·5 could be obtained, and measurements were made of the corresponding deflections of the electrometer needle. At quite slow speeds there was a complete absence of flicker and for a large range of speeds above the minimum, the needle was steady and constant. The results obtained were given in the original paper, and they show that there is an accurate linear relationship between the amount of light transmitted and the electrometer deflection over the range used.

(4) The Magnification of the Lens L_2.

A better lens has been used, and its magnification most conveniently and directly measured by mounting stainless steel wires across the metal guides in place of the yarn and measuring the corresponding electrometer deflections. This was repeated a large number of times and with varying slit widths, the mean value of the magnification thus obtained being 2·14.

THE THEORY OF THE LINDEMANN ELECTROMETER PHOTOELECTRIC CELL SYSTEM

In the original paper describing his electrometer, Lindemann[2] gives a complete account of the practical details of the instrument, and also the theory of it as far as steady applied voltages are concerned. The theory is here

extended to the case of continuously varying applied potentials such as would be produced by the varying currents from a photoelectric cell.

The free period of the electrometer needle *in vacuo* is about 0·15 seconds, and as supplied, air damping is not sufficient to render the motion of the needle aperiodic. Some experiments were therefore undertaken to investigate the effect on the maximum deflection of (*a*) electrical damping and (*b*) rate of application of potential to the needle.

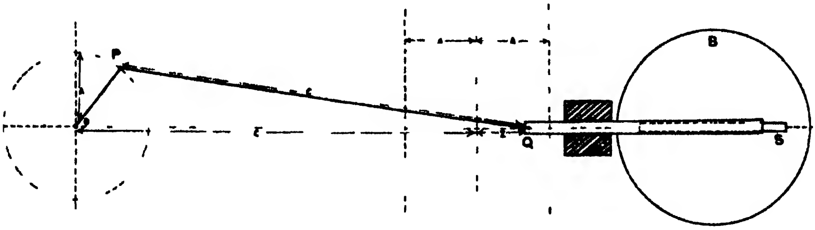

FIG 3

A small plunger with a flat strip at the end, driven by a crank and connecting rod from the motor used for pulling the yarn through, was arranged so as to move to and fro in front of the brass plate B, the slit S being completely covered at one end of the stroke and completely uncovered at the other end. Referring to Fig. 3, if z is the distance of the point Q from the central position at any instant, then

$$z=a\cos\theta+\sqrt{c^2-a^2\sin^2\theta}-c$$

$$\frac{dz}{d\theta}=-\frac{a\sin\theta\cdot(z+c)}{z+c-a\cos\theta}$$

In the experiments $c=17{\cdot}8$ cm. and $a=0{\cdot}15$ cm. so that $a\cos\theta$ can be neglected in comparison with $z+c$. Hence

$$\frac{dz}{d\theta}=-\ a\sin\theta \text{ (approx.).}\quad \text{i.e. } z=a\cos pt$$

where p is the angular velocity of the motor spindle.

The potential V applied to the needle at any instant can therefore be represented by

$$V=V_0+V_0\cos pt$$

Let C_2 be the capacity of the electrometer

C_1 be the added capacity

$C=C_1+C_2$

R be the series resistance.

Then if Q is the charge on the condenser C at any time t when the deflection is θ.

$$R\frac{dQ}{dt}+\frac{Q}{C}=V_0(1+\cos pt)$$

the solution of which is

$$Q=Ae^{\frac{-t}{RC}}+V_0C\ [1+L\cos(pt-\alpha)]$$

where

$$\tan\alpha=pRC \text{ and } L=\frac{1}{\sqrt{C^2R^2p^2+1}}$$

Hence as t increases the charge settles down to the steady oscillation.

$$Q=V_0C[1+L\cos(pt-\alpha)]$$

If the length of the needle is $2l_2$, the proportion of the charge Q on a small element dl of the needle at a distance l from the axis of rotation is

$$\frac{dl\cdot C_2V_0}{2l_2}[1+L\cos(pt-\alpha)]$$

and the turning moment in a field of strength F, which we have already shown to be uniform for small deflections, is

$$2\int_0^{l_2}\frac{dl.C_2V_0}{2l_2}[1+L\cos(pt-\alpha)]\,l.F.$$

$$=MV_0[1+L\cos(pt-\alpha)]$$

where $M=\frac{Fl_2C_2}{2}$

The rotation of the needle in the direction of the field induces a charge $C_2\frac{dl}{2l_2}\cdot F.l$ on each element dl, and the couple to which it gives rise is

$$2\int_0^{l_2}C_2\frac{dl}{2l_2}\cdot F.l.Fl.\theta$$

$$=\frac{F^2l^2{}_2C_2}{3}\cdot\theta$$

The restoring couple due to the torsion of the suspension wire is $\frac{\pi nr_1{}^4}{l_1}\cdot\theta$ where l_1 is the semi-length, r_1 the radius, and n the rigdity modulus of the wire.

The effective restoring couple is therefore

$$\left(\frac{\pi nr_1{}^4}{l_1}-\frac{F^2l_2{}^2C_2}{3}\right)\theta=G\theta$$

When the terms in the bracket become equal, which happens in the case of the present instrument when there is a plate p.d. of about 56 volts, the needle becomes unstable.

The couple due to air damping may be taken as proportional to the angular velocity of the needle, i.e. equal to $K\dot\theta$, so that the general equation of motion of the needle is

$$I\ddot\theta=MV_0[1-L\cos(pt-\alpha)]-G\theta-K\dot\theta$$

$$\text{or }\ddot\theta+\frac{K}{I}\dot\theta+\frac{G\theta}{I}=\frac{MV_0}{I}[1-L\cos(pt-\alpha)]$$

I. being the moment of inertia of the needle about its axis of rotation.

The term in the solution representing the free motion of the needle quickly dies out owing to the heavy damping factor $e^{\frac{-K}{2I}t}$ and the needle settles down to the steady oscillation given by

$$\theta=\frac{MV_0}{G}\left[1+\frac{L\sin(pt-\alpha-\alpha')}{\sqrt{\left(1-p^2\frac{I}{G}\right)^2+\frac{K^2}{G^2}p^2}}\right]$$

where $\tan \alpha' = \dfrac{\frac{K}{I}p}{\frac{G}{I} - p^2}$

giving a maximum deflection

$$\theta' = \frac{MV_0}{G}\left[1 + \frac{L}{\sqrt{\left(1-p^2\frac{I}{G}\right)^2 + \frac{K^2}{G^2}p^2}}\right]$$

The values of the various constants can be determined approximately from the following considerations.

According to the makers $l_2 = 9{\cdot}5 \times 10^{-1}$ cm

$C_2 = 1{\cdot}3$ cm. capacity.

The distance between the plates is 5×10^{-1} cm. so that

$$\frac{F'l_2^2C_2}{3} = \frac{70^2 \times 10^{-16} \times 9{\cdot}5^2 \times 10^{-2} \times 1{\cdot}3 \times 10^{-20}}{9 \times 3}$$

$$= 2{\cdot}13 \times 10^{-2}$$

assuming a plate p.d. of 35 volts.

When the needle becomes unstable at a p.d of $F^1 = 56$ volts we have

$$\frac{F'^2 l_2^2 C_2}{3} = \frac{56^2}{35^2} \times 2{\cdot}13 \times 10^{-2} = 5{\cdot}44 \times 10^{-2}$$

and this is equal to $\dfrac{\pi n r_1^4}{l}$

Hence $G = (5{\cdot}44 - 2{\cdot}13) \times 10^{-2}$

$= 3{\cdot}31 \times 10^{-2}$ dyne cms.

Also, since the free period of the needle *in vacuo* is 0·15 seconds, we have

$$0{\cdot}15 = \frac{2\pi}{\sqrt{\frac{G}{I}}} \quad \text{or} \quad \frac{G}{I} = 1{\cdot}76 \times 10^3$$

giving $I = 1{\cdot}88 \times 10^{-5}$ gm.-cm.^{2}

The solution for the free motion of the needle with air damping is

$$\theta = e^{-\frac{K}{2I}t}\left(A \cos\sqrt{\frac{G}{I} - \frac{K^2}{4I^2}}\cdot t + B \sin\sqrt{\frac{G}{I} - \frac{K^2}{4I^2}}\cdot t\right)$$

By a special arrangement of switch for short circuiting the plates, the needle could be so arranged to swing from a deflected position to its zero position freely, and it was found that the amount by which it swung below the zero position was twice the amount it went above next time. This measurement was only approximate owing to the quick movement of the needle, and no means of rapid photography were available at that time.

We have then

$$e^{-\left[\frac{K}{2I}\cdot\frac{\pi}{\sqrt{\frac{G}{I} - \frac{K^2}{4I^2}}}\right]} = 0{\cdot}5$$

which gives $\dfrac{K}{I} = 18$, i.e. $K = 3{\cdot}39 \times 10^{-4}$

The largest value of p^2 used in the experiments was 15·8. Using the values of the constants just deduced, we have

$$\sqrt{\left(1-p^2\frac{I}{G}\right)^2+\frac{K^2}{G^2}p^2}$$
$$=\sqrt{1+p^2\left(\frac{K^2}{G^2}-\frac{2I}{G}\right)+\frac{I^2}{G^2}p^4}$$
$$=\sqrt{1-p^2(1\cdot03\times10^{-3})+p^4(32\cdot3\times10^{-8})}$$

which even with the maximum value of $p^2=15\cdot8$ comes to 0·992 so that to the accuracy with which the deflection measurements can be made, this factor can be taken as unity and we then have

$$\theta'=\frac{MV_0}{G}\left(1+\frac{1}{\sqrt{C^2R^2p^2+1}}\right)$$

$$\text{or } d\propto\left(1+\frac{1}{\sqrt{C^2R^2p^2+1}}\right) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad \text{(A)}$$

In the series of experiments recorded in Table III the minimum and maximum deflections were measured for three different values of CR. at each speed. The three condensers used had capacities of--

(*a*) 0·0125 mfds.
(*b*) 0·0229 mfds.
(*c*) 0·0312 mfds.

The value of R was found by connecting a standard 0·5 mfd condenser in parallel with the electrometer and taking a record on the curve tracer of its rate of leak after being charged to a known potential. The potential V at any instant is then given by

$$\log V=\text{const}-\frac{t}{CR}\log e.$$

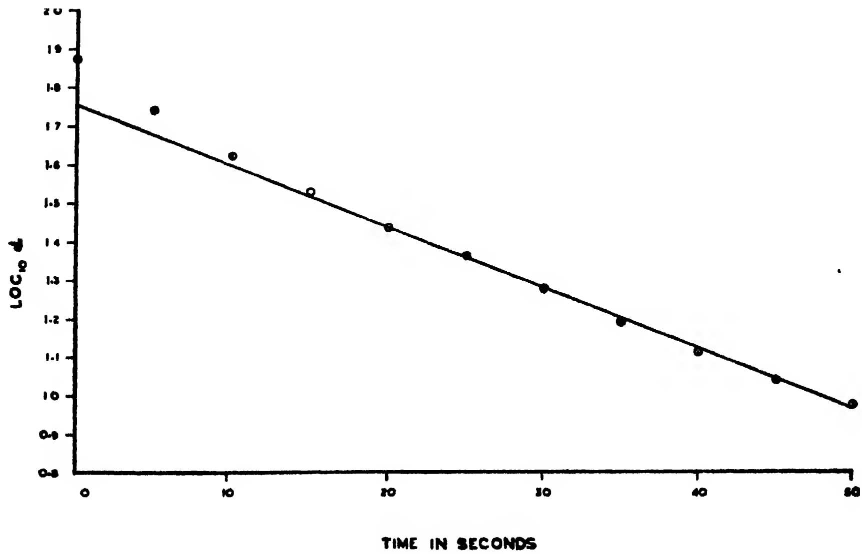

FIG 4 Curve showing Rate of Discharge of Condenser.

Readings were taken from the curve of the deflections at five seconds intervals and logarithms of the deflections were plotted against time (see Fig. 4). It will be seen that all the points, after the first three, lie on a straight line, so that over that region the motion of the needle is a true record of the decay in charge on the condenser.

The straight line can be represented by

$$\log d = -0{\cdot}0159t + 1{\cdot}76$$

giving $$CR = \frac{\log e}{0{\cdot}0159} = 27{\cdot}34$$

Since C=0·5 mfd, R=54·7 megohms.

Referring to Table III it will be seen that equation (A) is fully verified. The mean value of $\frac{x}{d}$ is 0·0220 and the differences from this are very small considering the variability of most of the factors involved in the measurements, showing that the agreement with the theory is quite satisfactory.

Table III

Plate potentials +20·38 volts
−14·55 volts
Zero reading 106 mm

Condenser used	T in secs	$p^2 - 4\frac{\pi^2}{T^2}$	Deflections Minimum	Maximum	d max 106	$C^2R^2p^2+1$	x $1+\frac{1}{\sqrt{C^2R^2p^2+1}}$	Ratio $\frac{x}{d}$
a	9·36	0·44	110·5	186	80	1 203	1·912	0 0239
b			112 5	184	78	1·69	1 769	0 0227
c			114	182 5	76 5	2 28	1 662	0 0217
a	5 48	1·304	112·5	181 5	75·5	1 607	1 789	0 0237
b			117	177	71	3·03	1 574	0 0222
c			118 5	175	69	4 80	1·456	0·0211
a	3·18	3·91	115	176	70	2·82	1·596	0·0228
b			123 5	171	65	7·13	1 375	0 0212
c			128 5	167·5	61·5	12 4	1 284	0·0209
a	2·50	6 32	118	173	67	3·94	1·504	0·0225
b			126 5	167	61	10·9	1·303	0·0214
c			131	164	58	19·4	1·227	0 0212
a	1 58	15·8	125	169	63	8·35	1·346	0 0214
b			132	162	56	25·8	1·197	0·0214
c			135	158	52	47·1	1·146	0·0220

THE SELECTION OF THE OPTIMUM CONDITIONS FOR PRACTICAL USE

The question now arises as to the optimum conditions of electrical damping and speed of traverse of yarn for use in practice. If we assume for the moment that we can allow a 5% variation in the maximum value of the difference between the actual diameter of a yarn at any point, and the mean diameter, we must have

$$\frac{1}{\sqrt{C^2R^2p^2+1}} = 0{\cdot}95, \text{ i.e. } CRp = 0{\cdot}33$$

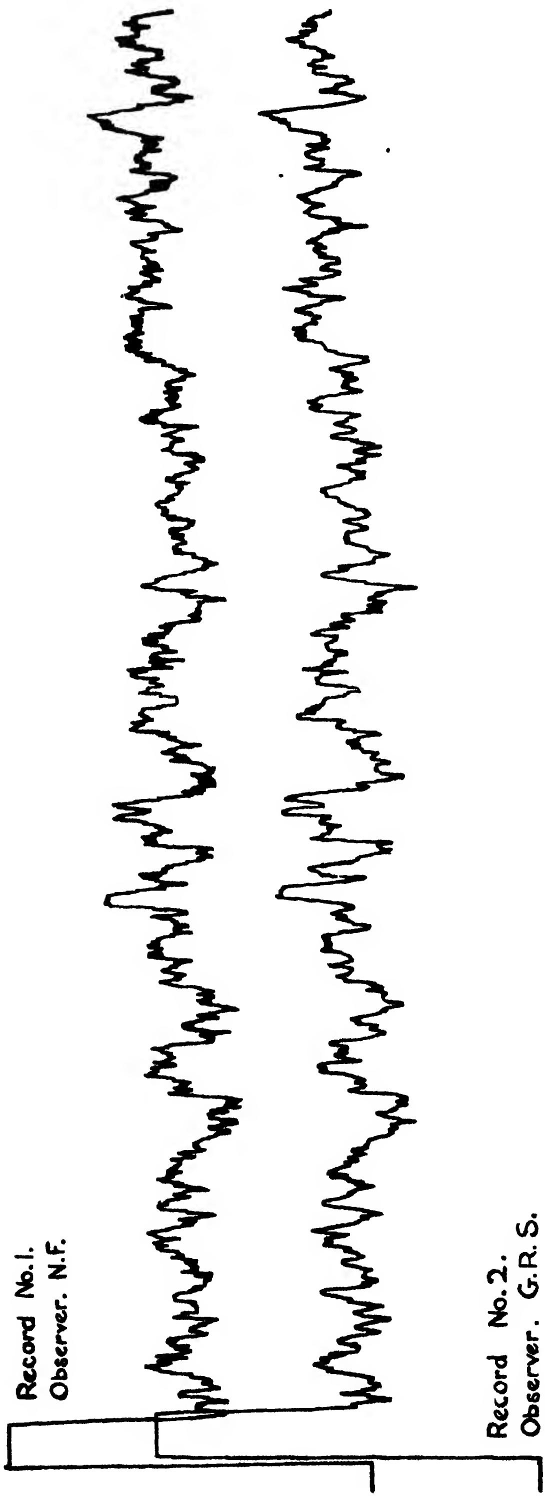

FIG 5 Levelness Curves by Different Observers for the same Stretch of Yarn

In practice, periodic variations which exist in yarns over shorter lengths than 1 inch are not important.

A convenient speed of traverse for following the motion of the needle is 1·5 feet per minute, i.e. 0·3 in. per second, giving $T=\frac{10}{3}$ and $p=1{\cdot}885$.

Since R is fixed at 54·7 megohms. the only other adjustable factor is the capacity which must therefore have the value

$$C=\frac{0{\cdot}33}{54{\cdot}7\times 1{\cdot}885}=0{\cdot}0032 \text{ mfd.}$$

PRACTICAL TESTS USING THE OPTIMUM CONDITIONS

Some doubt was felt as to the accuracy with which the movement of the image of the needle across the scale could be followed by hand, and a number of records were made to make sure that any record could be reproduced with the same stretch of yarn. One of these was reproduced in the original paper. Fig. 5 is a reproduction of a record of a typical worsted yarn. When the first record was made the yarn was marked at each end and was then run through again at the same speed and under the same tension, and another record obtained on the same chart by a different observer. The accuracy with which the two traces agree shows that when sufficient skill has been acquired, there is little difficulty in following the movement of the needle.

This difficulty has, however, been entirely overcome by the installation of a recording camera in place of the pen recorder. The fluctuations of the needle image are focussed by means of a cylindrical lens on to a continuously moving strip of photographic paper, the driving mechanism of which is driven from the same motor which draws the yarn past the slit, thus ensuring a constant relation between the length of the yarn and the length of the record. A typical photographic record is reproduced in Fig. 6.

The way in which the peaks and depressions in the curves correspond with the variations in levelness of the yarn is shown clearly in Fig. 7. This is a photograph of a demonstration card on which the actual yarn used in making the record was mounted above the record itself. Each of the eight V-shaped sections of the yarn correspond to each of the eight main divisions of the record. The recorded diameter of any part of the yarn can then be found by drawing a line perpendicular to the length of the record. It will be seen how well the record follows the variations in diameter of the yarn along its whole length.

A more accurate test was made by replacing the normal roller used for drawing the yarn through by another which had a very fine projecting ridge running parallel to the axis along the whole of its length. This roller had a circumference of 1·19 in. and it was arranged that the ridge could be moistened with ink once every revolution, so that a fine mark could be made on the yarn at every successive 1·19 in. The yarn was afterwards conditioned for several days in a room kept constant at 70% relative humidity and 73° F. temperature. Successive 1·19 in. were then cut off and weighed on a special form of microbalance. Assuming the density of the thread to be constant along its length, the diameter at any point will be proportional to the square root of the mass per unit length. Hence to show the comparison between the two sets of measurements, the square roots of the weights (in micrograms)

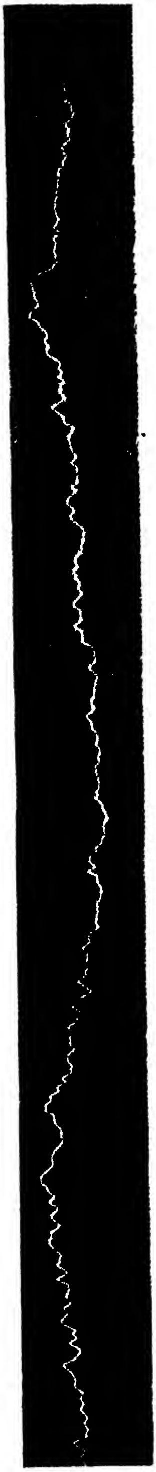

Fig 6 Photographic Record The Diameter at any Point is Proportional to the Perpendicular Distance from the Base Line.

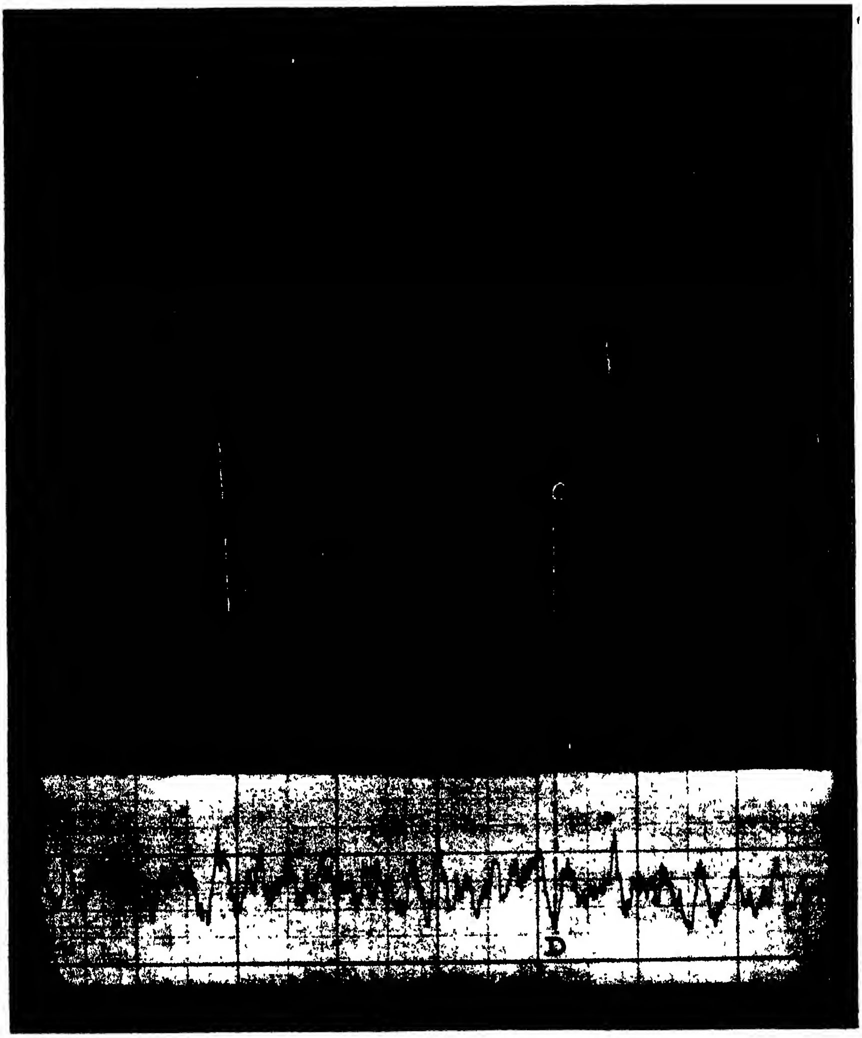

FIG. 7. Photograph of a Sample of Yarn Mounted above the Corresponding Levelness Record.

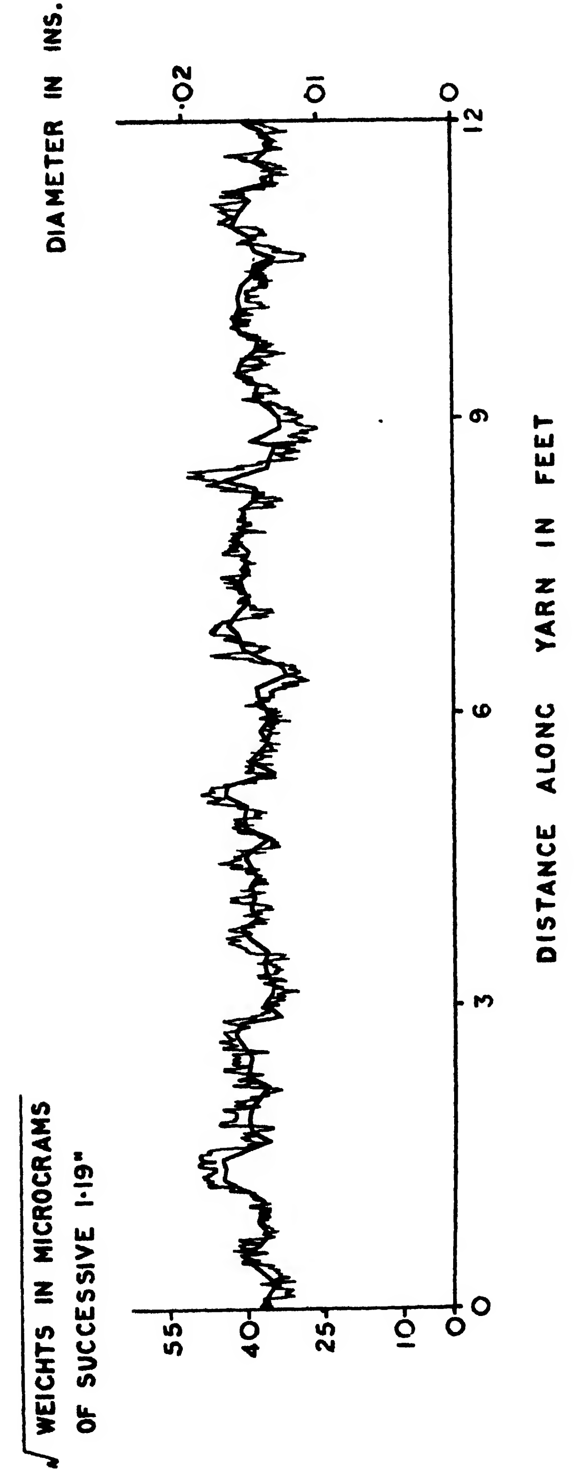

FIG. 8. Record showing Relation between Levelness Curve and Weight per Unit Length Curve.

of successive 1·19 in. lengths have been plotted over the record, showing the variation in diameter (see Fig. 8). The zero of the readings was made to coincide with the zero of the diameter record and the scale was adjusted so that the square root of the mean weight (156 micrograms) coincided with the mean diameter which had been calculated from the record by measuring up the area between the record and the base line with a planimeter and dividing by the known length. The whole length of the record, which represented 12 feet of yarn, was divided up into 121 equal sections of 1·19 in. each and the corresponding value of the square root of the weight was plotted at the middle of each section and successive points joined up by straight lines.

The two curves show remarkable agreement considering all the factors involved. The diameter curve, of course, shows more of a point to point variation since it registers the mean diameter of a length of about 0·1 in. of yarn, whereas the weight method averages up 1·19 in. of yarn. We would expect the latter, therefore, to show smaller variations, and this is certainly the case. Moreover, a thick place in a yarn is usually accompanied by less twist, so that as there are more air spaces in the interior of the yarn, its density will be less and the corresponding weight will be proportionally less. Similarly when the density is above the average, e.g. at a thick place where the twist is high, the weight will be proportionally higher. Hence, all the way along, we should expect the weight curve to be within the diameter curve, and it will be seen that this is so with very few exceptions.

It is just interesting to note that the values for the mean diameter and the mean weight per unit length give a value for the mean density of 0·543. The actual density of the wool itself at 70% R.H. is about 1·32 so that actually more than half the volume of the yarn consists of the air spaces between the fibres.

TESTS OF "STANDARD" YARNS

Table IV gives the results of some tests on a number of "standard" worsted yarns, i.e. yarns of good commercial repute.

Table IV

Quality	Count		Turns per inch	Mean Variation from Mean		Mean Diameter in inches
	Specified	Measured at 70% R.H. and 73° F.		Actual in inches	Percentage of Diam.	
80's	1/70	69·5	20·9	0·00089	12·6	0·0070
	2/70	35·8	24·0	0·00098	9·4	0·0104
70's	1/60	61·0	18·8	0·00080	10·1	0·0079
	2/60	30·7	20·5	0·00091	7·9	0·0115
	1/60	60·4	18·8	0·00091	10·8	0·0084
	2/60	30·0	20·5	0·00093	8·0	0·0116
	1/48	49·5	15·6	0·00085	9·8	0·0087
	2/48	24·5	16·0	0·00076	6·1	0·0124
64's	1/48	46·4	15·2	0·00089	10·0	0·0089
	2/48	33·9	15·0	0·00084	6·5	0·0130
	1/48	46·5	15·2	0·00089	10·0	0·0089
	2/48	24·4	15·0	0·00089	5·9	0·0130
70's	1/32	32·2	10·4	0·00077	7·1	0·0120
	2/32	16·6	9·5	0·00085	4·7	0·0171
	1/24	24·5	8·5	0·00105	7·0	0·0150
	2/24	12·2	7·3	0·00060	3·3	0·0183

These are only typical of hundreds, but they are rather interesting in that they show that over a range of counts from 24's to 70's worsted, and with single and twofold yarns, the actual mean variation is the same. This fact is masked when the variation is expressed in the usual way; that is as a percentage of the mean diameter. This means that the variation in say 1/48's yarn is not measurably different from that in a 2/48's. The operation of folding, however, by increasing the diameter, has reduced the percentage variation. The figures also suggest that there is very little advantage from the point of view of levelness of say a 2/48's over a 1 24's, both having the same actual and percentage variation.

The author's thanks are due to Mr. N. Fishburn, who has ably assisted with the experimental work.

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[2] Lindemann, F. A. and A F, and Keeley, T C Phil Mag, **47**, March 1924

28—THE GEOGRAPHICAL BASIS OF THE IRISH LINEN INDUSTRY

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One of the most prominent features in Irish geography is the position of Belfast, not only as the centre of the linen industry in Ireland, but also as the linen metropolis of the world. Diagrams 1 and 2 shows the general distribution of the linen manufacture throughout Europe where regional concentration

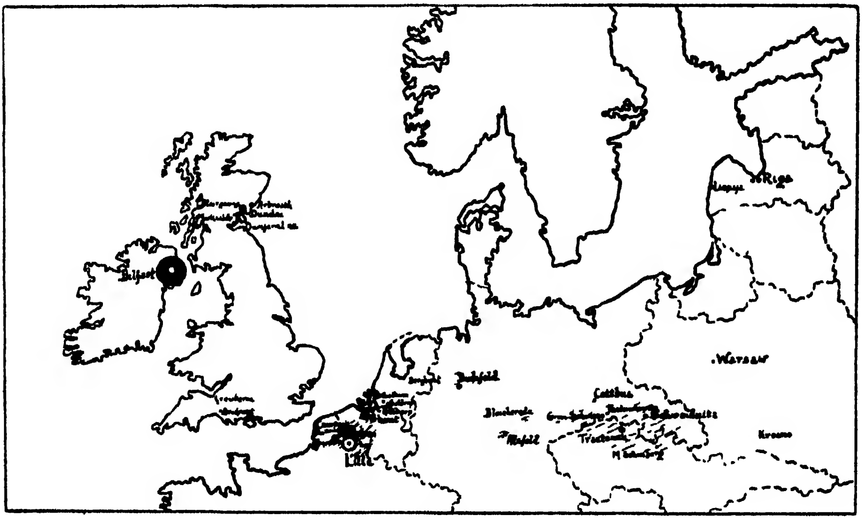

DIAGRAM 1
Distribution of Linen Manufacture in Europe (diameters of circles proportional to the number of firms).

appears in three areas, viz., north-east Ireland, north-east France and Belgium, and the districts of Saxony, Silesia, and Czecho-Slovakia about the Riesen Gebirge and Sudetic Mountains. The predominance of north-east Ireland is evident both as regards the number of firms engaged in the industry and the spindleage of the mills.

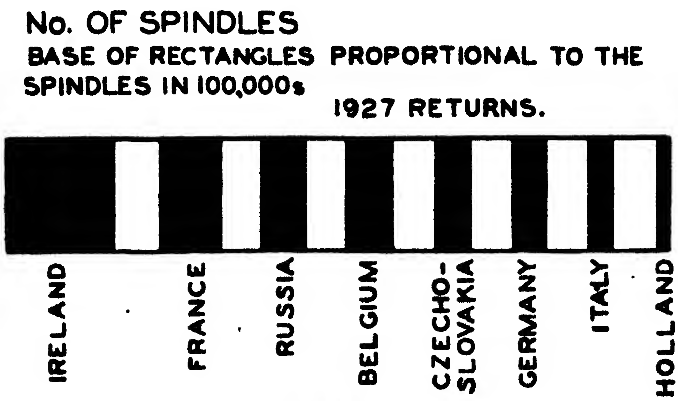

DIAGRAM 2

The industrial revolution and the commencement of the age of competition generally changed old geographical relationships and brought about fresh groupings; physical causes operated towards these new arrangements, the most powerful of which were the soils of Ireland, the character of its natural waters, its type of climate, and the position relative to sources of power.

A soil map of Europe illustrates the great extent along the sea board of the North and the Baltic Seas of a vast area of land of the podzol type. It stretches away into Russia and occupies at least two-fifths of that country. The term podzol implies a thoroughly washed out soil of rather coarse granular structure, varying in its mineral contents according to the nature of the underlying rock The south of the podzol belt is richer in humus than the north owing to a warmer climate and a richer vegetation; the north is more covered with moss lands and beds of peat. Flax growing is localised along the podzol in an intermediate position with a slight tendency to the north. Diagram 3 illustrates this distribution and indicates a concentration in north-east Ireland, Belgium, Esthonia, Latvia, Lithuania, and especially Russia. The last named produces the greatest portion of the world's flax supply and yet manufactures comparatively little in factories.

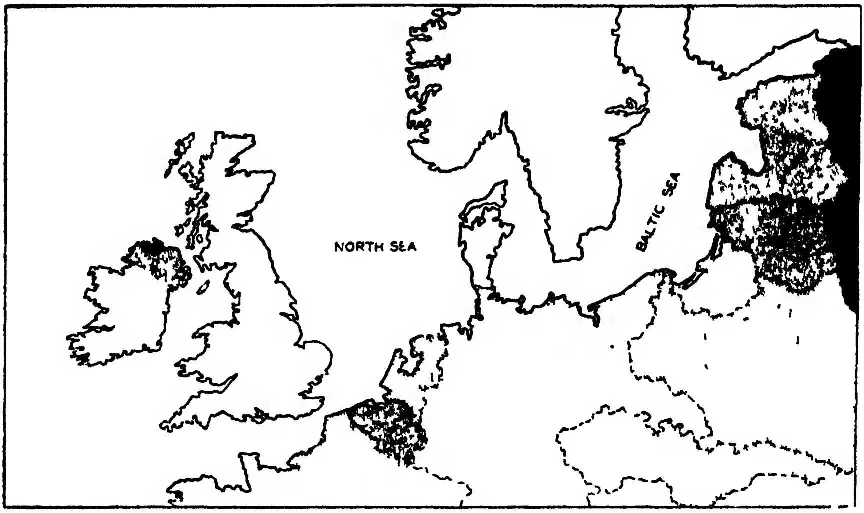

DIAGRAM 3

Distribution of Flax Culture around the Baltic and North Seas
(One dot = 100 acres, three years' average 1925-27)

The flax plant does not grow well on a peaty soil as it cannot produce the best fibres, neither has it been able to maintain a position on the richer podzols owing to the competition of other crops and to the tendency to grow up soft, and to lack that rigidity which the proper development of the ring of strengthening fibres gives it; there is also a possibility for it to become more oleaginous than fibrous Its concentration in north-east Ireland can perhaps be best explained by a reference to Diagram 4, which indicates the varying yields from different types of soils around Selby in Yorkshire In this area a considerable amount of flax is grown and a careful record has been kept of the yield of fibre per acre and the results plotted on the diagram. Limestone soils give the heaviest returns, and alluvial and clay soils give the next best

results. A geological map of Ireland shows the limestone region occupying the whole of the central part and most of the south, whilst the north consists of a large basaltic plateau in Antrim and ancient metamorphic rocks in Derry and Donegal with Silurian grits and shales in Down, Louth, and Meath. Although all these rocks yield a soil of the podzol type owing to the heavy rainfall of the region fundamental differences seem to persist. The glacial soils of the central plain vary from stiff heavy loams to open sands. Like most limestone soils they tend to remain as pasture lands and are remarkable

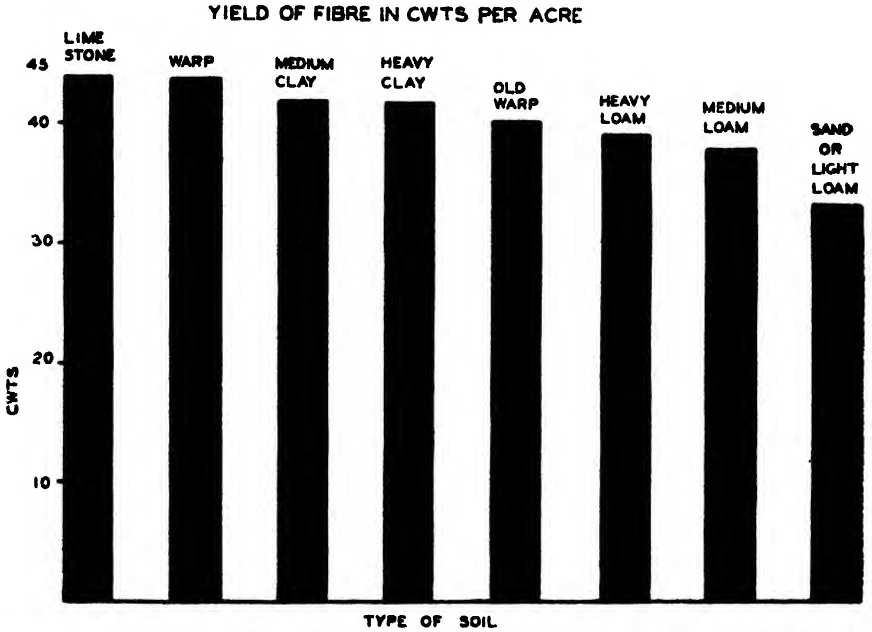

DIAGRAM 4

Summary of Yields of Flax Crops grown on different soils in Yorkshire in the Years 1928-1929

for the sweetness and luxuriance of their vegetation. They are naturally good stock raising lands In the south the rich lands, some of limestone formation and some derived from the Old Red Sandstone seem to be suited to grazing and tillage, and dairy cattle predominate in this region as well as in the mixed lands around Sligo. The rearing of dairy cattle in Cork and Kerry has also been aided by the mildness of the winter climate, and thus the soils of the south and centre have been turned to the development of other branches of husbandry through the growth in demand of the British market for provisions; one marked feature of the development has been the increase in the number of creameries. This economic departure in the use of the land has been contemporaneous with the decay of flax culture in central and southern Ireland from 15,129 acres in 1851 to 299 acres in 1926. A similar movement seems to have occurred in north-east France. Prior to 1862 the cultivation of flax dominated the basin of the Somme and extended westwards into Normandy. The fertile lands of the Oise and Somme bore rich harvests. Then came the development of the beetroot and its use in the sugar-making

industry; flax was unable as an economic crop to withstand its competition for the use of these richer soils. It withdrew northwards from the hard waters of the Somme to the soft waters of the Lys, from the rich alluvial lands of Picardy to the colder clays of Belgium. Diagram 5 illustrates this movement and shows the present distribution of the flax industry in the middle reaches of the Lys and the development of sugar factories in the Somme basin. A parallel movement took place in Russia. The beetroot was introduced into the province of Kiev in 1836. Progress was at first slow but by 1881–2 over 600,000 acres were under cultivation. Flax culture declined in these southern lands and localised itself in the north-west in a region stretching eastwards from Leningrad beyond Moscow. To-day flax is the principal economic crop of the peasant in northern Russia, the mainstay of the countryman in the Lys valley, and the most important of the three marketable crops of the Ulster farmer. In Ulster, potatoes, oats, and flax are the crops sold off the holding, and the last named constitutes 30% of the total flax used in the linen industry of northern Ireland. There is here a body of about 70,000 holders with farms of 10 to 100 acres which they cultivate by the help of their families, they constitute an important element in the social and economic life of agrarian Ulster.

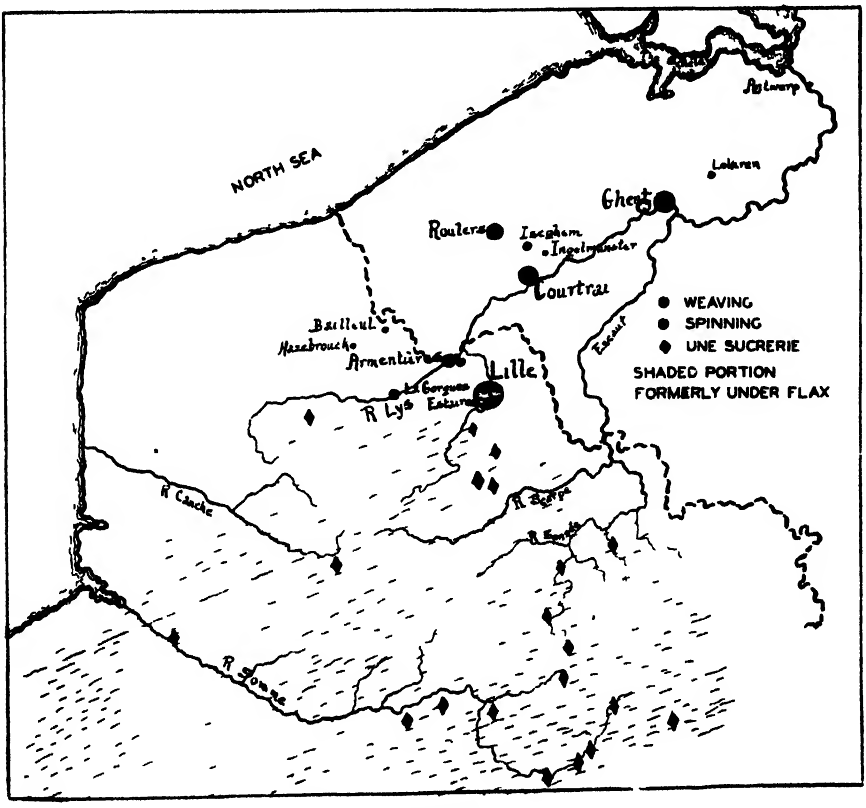

DIAGRAM 5

The Distribution of the Linen Industry in the Valley of the Lys, and the Distribution of the Beetroot Sugar Industry in the Basin of the Somme

Thus although flax growing has not been able to maintain its position on the best lands against the competition of other branches of husbandry in the countries selected it has survived as a most important industry on the next best soil largely from the fact that the clay regions of northern Ireland and the Low countries are areas with abundance of soft waters. On Diagram 6 are plotted the available analyses of stream waters in Ireland. The central plain and most of the south return exceptional degrees of hardness for surface flows ranging from 12 to 30; in the north there is no degree of hardness greater than 8·5, and the usual amount is between 3 and 4. The relation of hard and

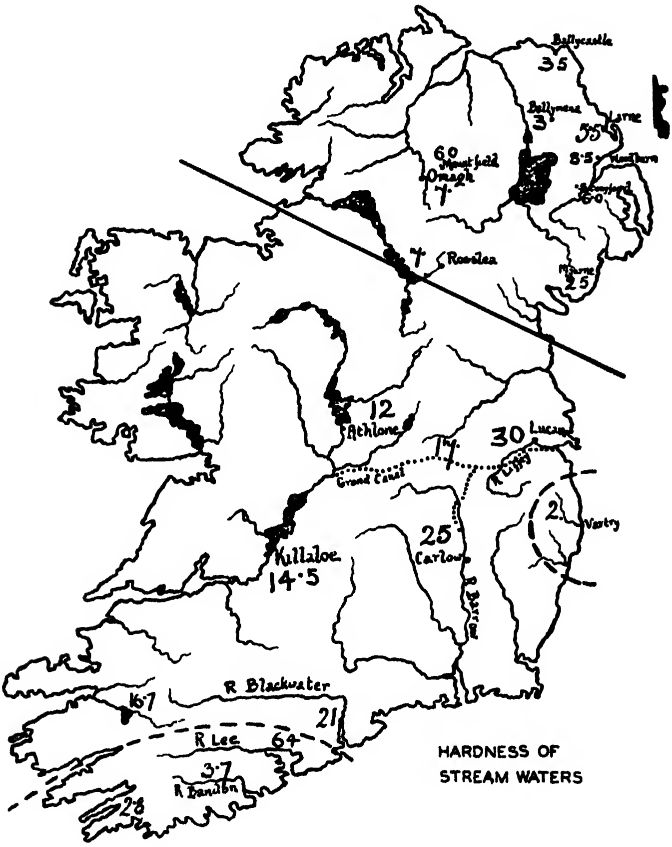

DIAGRAM 6

soft waters to the linen industry is perhaps most important in the retting of flax. Flax retted in dams filled with soft water will ret in less time than in hard water, and the shorter the time taken in the retting process the less the possibility of any deterioration of the fibre. Again in dry, warm weather retting takes less time than under cold and wet conditions; the temperature factor is evidently important. The temperature of Irish retting pools is not much above 50° F. in the retting season; this is lower than that of the Thirlmere waters of the Manchester Corporation Waterworks and very much below that of the River Lys. The differences are shown on Diagram 6. Irish waters are therefore at a disadvantage in this respect and Belgian flax has always occupied a strong position in competition with Irish. The River

Lys has a further advantage in its exceptionally slow current in which the crates containing the flax are immersed. The slow percolation of the river water through the jute sacking around these crates seems to bring about by natural means that gradual and necessary replacement by fresh water of the acid waters produced by the fermentation of the retting process. The modern development of a rettery where water heated from 60° to 90° is made to circulate slowly through the immersed flax is overcoming the natural disadvantage of Irish waters in respect of temperature. Dew retting is also practised in Ireland, but more largely in Russia, especially where humidity of the air and the diurnal temperature changes are such as to cause a sufficient frequency in the fall of dew. Districts and years vary in this respect to such a marked degree that three weeks suffice in some places and five or six in others; the longer period causes a marked deterioration of the fibre. The humidity of the air in northern Ireland is greater than in south Ireland, and this greater humidity is necessary not only for dew retting but also for linen manufacture. Actually a greater relative humidity is required for linen than for cotton, and the figures for some of the important stations are given on Diagram 8.

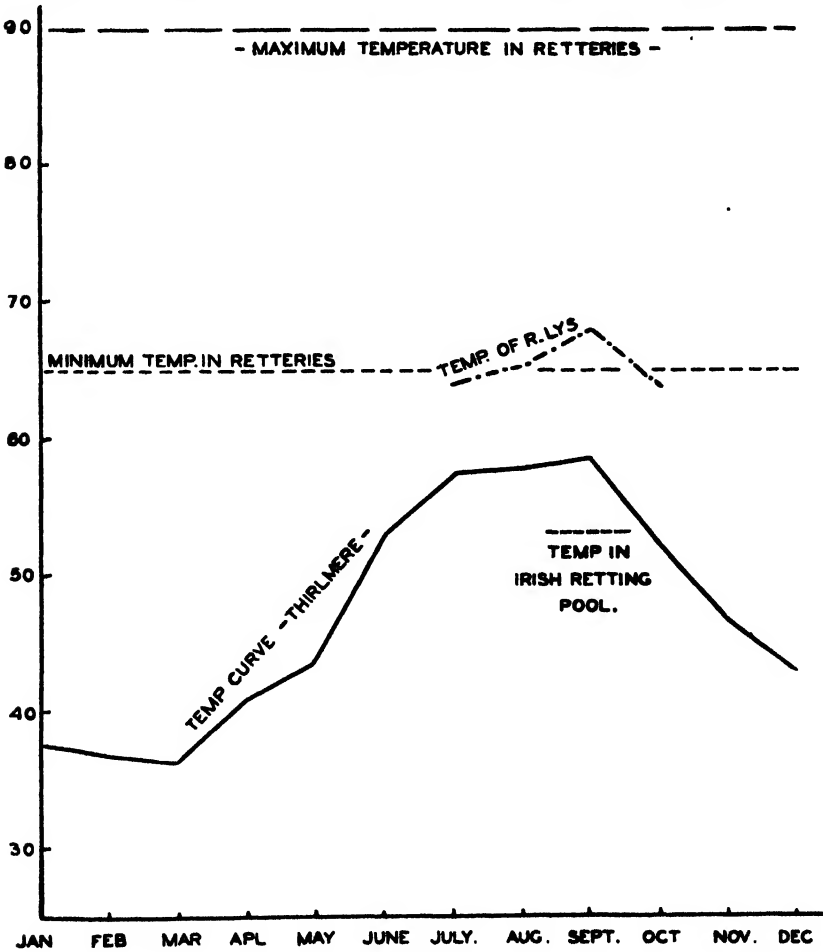

Diagram 7

Valentia in south-west Ireland has a relative humidity generally less than that of Armagh, a linen centre in the north. The humidity of Ghent and Courtrai are not available, but the nearest station, Brussels, has been taken as approximate in humidity to the linen region of the Lys valley. All stations have a much greater humidity than Manchester, and it is possible that these differences in humidity have had some effect in bringing about the regional distribution of linen and cotton. Belfast in the early part of the 19th century was a cotton town but changed over to linen.

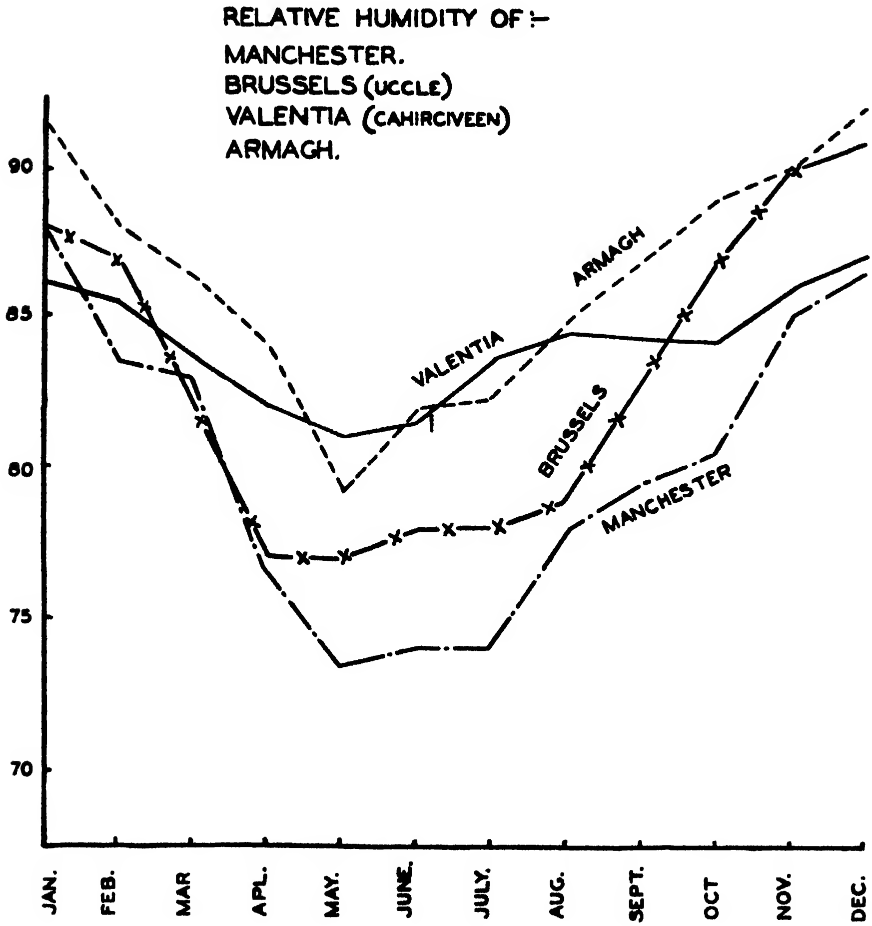

Diagram 8

The industrial revolution found Ireland short of the main source of power—coal. The largest coalfield is around Lough Neagh, but the proximity of north-east Ireland to the coalfields of Scotland and Cumberland and the easy water communication inland have placed the region in an advantageous position for the application of steam power and machinery to the linen industry. The first steam-driven mill was established by John Mullholland in Belfast in 1829. By 1838 there were 40 mills and in 1853 the number had increased to 80. Concentration of these mills into the north-east region has

been a feature of the last 80 years and now the movement is practically complete. Diagrams 9 and 10 illustrate the distribution not only of the mills but also of the processes of scutching, bleaching, and dyeing; the latter are carried out in small centres and are a feature of a village or small town. The mills bring about the rise of larger towns. Similar results occur in the Lancashire cotton industry. Thus northern Ireland by the possession of well-marked physical characteristics—a suitable soil, soft waters, a humid atmosphere, and proximity to sources of power, has been able to draw to itself one of the most ancient and important of the textile industries.

DIAGRAM 9

It remains to explain why the industry should centre in Belfast. Diagram 11 shows the north-eastern region pierced by two sea loughs projecting towards Lough Neagh, the centre of the hydrographic system of the Lagan and the Bann, which take their sources in Slieve Croob and the Mourne Mountains respectively. The lowland region into which they flow is easily canalised and through water transport is possible for barges drawing 4 ft. 6 in. by the Lagan navigation on the east, the Newry canal to the south, and the Ulster canal to

the west. The rainfall on the Mourne is approximately 70 in. annually, and being of the cyclonic type a constant supply of water is maintained in the rivers. Prior to the introduction of steam these upland streams provided the motive force for the early power mills. Some of these still exist and still use water power adapted to-day to the turbine. At one end of the through waterway is Newry, at the other Belfast, and between them are several centres of linen manufacture, one of the most important being Lisburn, the adopted home of Louis Crommelin in the latter part of the 17th century and still a place noted for its bleach greens.

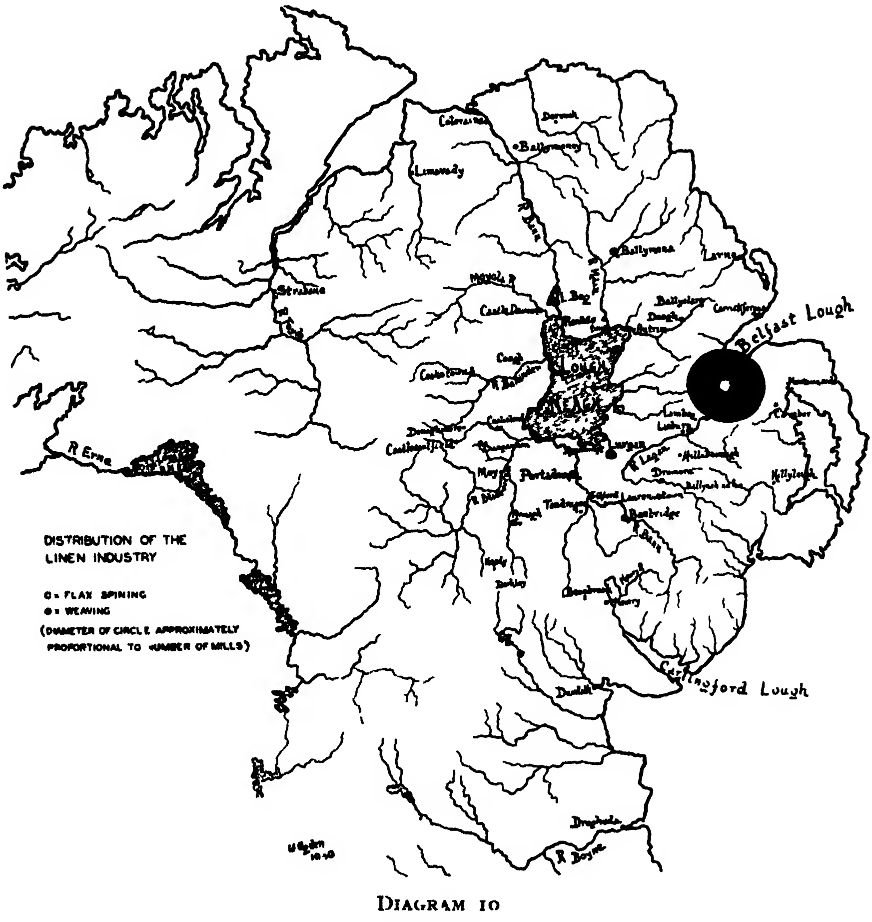

DIAGRAM 10

The Antrim coast generally is devoid of indentations suitable for a modern port. The 500 ft. contour runs very close to the coast and is pierced at only two places—Larne and Coleraine. There is no easy way from the coast to the interior except at Belfast and Carlingford Loughs. Of these the former possesses the more favourable geographical position. Carlingford Lough suffers from certain disadvantages; it is at the south end of the industrial region and narrows considerably in its upper reaches; it is only 10 ft. deep at low tide and the Newry canal, although commenced as early as 1730, has not kept up to modern requirements. It is 13 ft. 10 in. deep, but its methods of

handling cargo are not up to date. Belfast Lough is in the very centre of the industrial region, near to the source of power and at the point where the natural routes from Antrim meet those from Armagh and Down. The improvement of the harbour has been adapted to modern requirements and the broad valley leading down to it has come to depend for its continued prosperity upon an overseas market. Linen exports form approximately 32% of the export trade of northern Ireland.

DIAGRAM II

The Hydrographic Systems of the Bann and Lagan and their relation to Belfast Lough and Carlingford Lough.

In this great valley there is a coincidence of port facilities with the region of soft waters and at the same time proximity to power. Thus Belfast is not only the great manufacturing centre of the linen industry but also the principal market and warehouse for both flax and linen. In this respect the linen region of Ireland may be contrasted with the cotton region of Lancashire. The cotton port of Liverpool is far distant from the soft waters of the Pennines and the power of the south Lancashire coalfield. Thus the cotton region has two centres—the port at Liverpool and the centre of the manufacturing and warehousing at Manchester (see article on "The Geographical

Basis of the Lancashire Cotton Industry," *Journal of the Textile Institute*, Vol. 18, No. 11, 1927; or the *Journal of the Manchester Geographical Society*, Vol. 43, 1927).

Belfast alone dominates the linen industry. As the labour employed in the industry is about 75% female, the establishment of other industries for male labour, especially shipbuilding, has brought about an economic balance for male and female labour so necessary for the preservation of the family unit—the basis of our social and national life. There has then developed during the 19th century at this point a great human community with a large civic life which finds expression in its public buildings, its wide and well-planned streets, and its University. Here also are great mercantile interests represented by the character of the liners that call there and the volume of trade which passes through its docks. Its continued prosperity depends upon the prosperity of its hinterland with its linen industry. There is a natural background on which economic evolution and economic forces shape the development of an industry and the groupings of mankind in towns and cities. It is this natural background the writer has attempted to present and explain.

The author wishes to acknowledge the kindness and assistance of the many people who have helped in the collection of the material for this essay, among whom are Professor Wilson, of Belfast University, Dr. Fagan, of Dublin, and Mr. O'Mahony, F.C S., of Cork, for the data respecting the hardness of waters; Mr. Twoomey, of the Department of Agriculture, Irish Free State; The Linen Research Institute, Lambeg; Mr. Holme Lewis, City Water Engineer, Manchester; and especially Mr. Medcalfh, of the Flax Tow Manufacturers Ltd., Selby, Yorkshire.

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29—MEASUREMENT OF THE VISCOSITY OF SOLUTIONS OF CELLULOSE IN CUPRAMMONIUM HYDROXIDE SOLUTION

A CAPILLARY TUBE VISCOMETER

By R. W. Kinkead

(The Linen Industry Research Association).

For an investigation in this laboratory it was found necessary to have an accurate method of measuring the viscosity of solutions of cellulose materials in cuprammonium hydroxide solution when the viscosity was comparatively low, i.e. when the log. of the viscosity of a 2% solution was below 0·5.

Two methods of measuring the viscosity of cuprammonium solutions are in general use. (1) Measurement of the time of fall of a sphere of known size and density through a known depth of solution. (2) Measurement of the time of flow of a definite volume of solution through a capillary tube. Tankard and Graham[1] give a summary of the work previously carried out on the viscosity of cuprammonium solutions and have designed a modification of the falling sphere method, tabulating log. viscosities as low as $\bar{1}{\cdot}12$ for a 2% solution.

For the purpose in view none of the methods for measurement described in the literature were found to be satisfactory. The falling sphere method was first employed using apparatus based on that designed by Gibson, Spencer, and McCall,[2] and measuring the time of fall through the liquid of small steel balls. The time of fall of a $\frac{1}{32}$ inch steel ball through the solutions, the viscosities of which were desired, was found to be much too short to be measured with the accuracy required. The results obtained were of the same order as those tabulated by Tankard and Graham, a time of fall of 5 seconds corresponding to a log. viscosity for a 2% solution of approximately $\bar{1}{\cdot}8$.

(*Note*—The apparatus used was not of the same dimensions as that of Tankard and Graham. The tubes were of diameter 1·3–1·5 cm. and the time of fall was measured through 5 cm. after the ball had fallen through 15 cm. of liquid. The concordance between the two sets of results should therefore not be stressed). A time of fall of 5 seconds was found to be about the lowest limit at which the results could be relied upon, for when the time of fall was about 2 seconds repeated experiments gave a log. viscosity varying between $\bar{1}{\cdot}18$ and $\bar{1}{\cdot}6$ for a 2% solution, the concentration of the solutions actually measured being 2·3 to 2·5 per cent.

All viscosities in this paper are expressed as the log. viscosity of a 2% solution. In the actual measurements more concentrated solutions were employed and the log. viscosity for 2% solutions calculated from a formula derived from that given by Farrow and Neale[3]—

$$\log.\,\eta_2=\log.\,\eta_B+\frac{22\,(\log.\,\eta_m-\log.\,\eta_B)}{11m+(2-m)\,(\log.\,\eta_m-\log.\,\eta_B)}$$

where η_B=viscosity of the cuprammonium hydroxide.

η_m=viscosity of m% solution.

η_2=viscosity of 2% solution.

An Ostwald capillary viscometer gave a value for log. $\eta_B=\bar{2}{\cdot}15$. The possibility of such large variations as were found when the time of fall was below 5 seconds made the falling sphere method of measurement quite unsuitable for use in the problem under investigation.

Gibson, Spencer, and McCall,[3] Nakano,[4] and Clibbens and Geake[5] have designed apparatus for measuring the viscosity depending upon determination of the time of flow of the solution through a capillary tube. Gibson, Spencer, and McCall first proved the necessity of excluding all air from the apparatus. They accomplished this by filling the viscometer with hydrogen, whilst Clibbens and Geake eliminated all gas by filling the viscometer entirely with the solution.

Clibbens and Geake's apparatus has the disadvantage that air is admitted to the viscometer as the time of flow is being measured so that duplicate observations cannot be carried out. In addition, with the procedure of Clibbens and Geake, the observed time of flow must be corrected for kinetic energy effects. Some experiments were made with Nakano's viscometer, which is a modification of the usual form of Ostwald viscometer, air being replaced by inert gas. The apparatus has not been found very satisfactory in practice as it is somewhat complicated, easily damaged, and very difficult to clean thoroughly.

All the apparatus mentioned was designed for use with cotton and the dissolution of the material takes place in the viscometer itself. This procedure would not be satisfactory with linen materials which often contain considerable quantities of substances insoluble in cuprammonium and so the solutions require filtration before estimating the viscosity.

The viscometer to be described follows the lines of the hydrogen capillary viscometer of Gibson, Spencer, and McCall. Any number of determinations of the time of flow can be made, corrections for kinetic energy are of little importance, and the apparatus is simple, easily cleaned, and can be calibrated with a liquid of known viscosity.

It is proposed in future work to retain the falling sphere method for liquids having a log. viscosity of 0·5 or more for a 2% solution and to use the capillary tube viscometer where the log. viscosity is below 0·5. The method now to be described has the advantage that dissolution of the material takes place apart from the viscometer. The method of preparing the solutions and the apparatus employed is described in Memoir No. 63.[6] Whilst this may make the procedure as a whole more complicated it is a decided advantage when dealing with linen materials as the portion of the linen complex insoluble in cuprammonium is of considerable importance and can be filtered off and examined. Also such filtration excludes any possibility of the capillary becoming clogged by solid matter. After some experience a good idea of which method of measurement should be employed can be obtained by observing the fluidity of the liquid on shaking the vessel in which the solution has been made. As the two methods give results in very good agreement the possibility of deciding on the method of measurement after the solution has been made is of great practical utility.

With the falling sphere method it was found necessary to use at least a 2·3% solution of the cellulose material when dealing with a solution of log. viscosity below 0·0, and even with this comparatively high concentration, in some cases a $\frac{7}{32}$ inch steel ball fell through 5 cm. of the liquid too rapidly for the time to be measured. Increasing the concentration of the cellulose would increase the time of fall, but with a concentration greater than 3% it is often difficult to obtain complete solution within a reasonable time.

With the tube viscometer method the time of flow through the capillary of a 1% solution of a certain material was 57·4 seconds, giving a log. viscosity

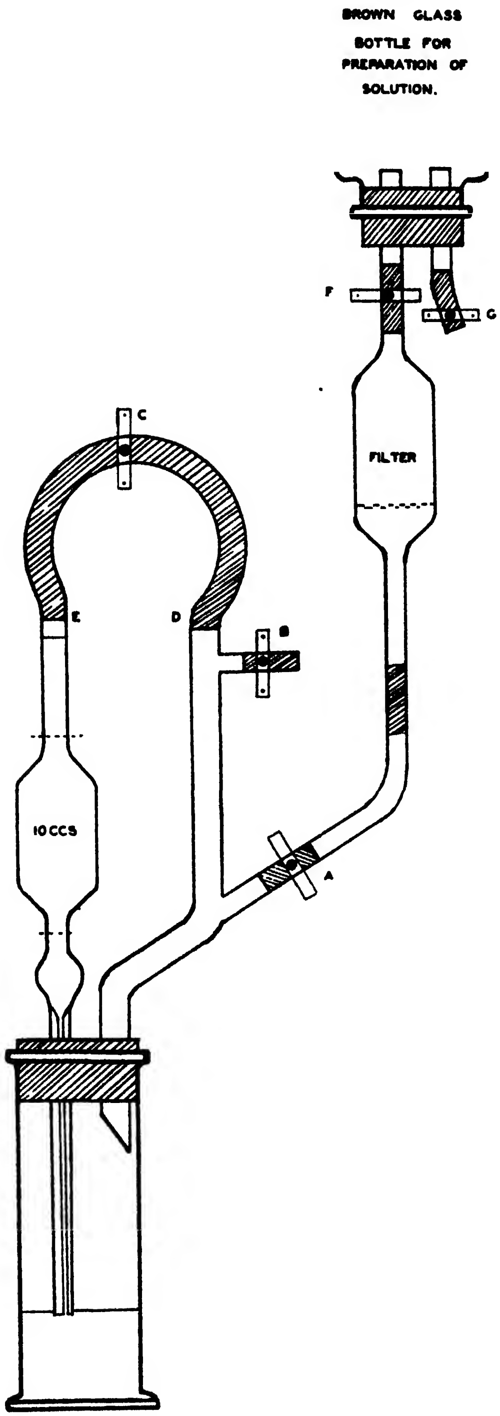

Diagram of Capillary Tube Viscometer

of $\bar{1}\cdot15$ for a 2% solution. A 2·8% solution of the same material allowed a $\frac{1}{32}$ inch steel ball to fall through a depth of 5 cm. in less than 1 second. When the log. viscosity is between $\bar{1}\cdot5$ and 0·75 the usual time of flow through the capillary of a 1% solution is 90–500 seconds. The capillary tube viscometer has not been employed for log. viscosities above 1·0 as then the rate of flow is very low and the solutions do not give a true viscous flow. The falling sphere method is more satisfactory in such cases.

The results were in good agreement with those obtained from the falling sphere method and at low viscosities repeated experiments gave results much less erratic than those obtained with the falling sphere. Typical results are tabulated—

Falling Sphere			Tube Viscometer		
Conc. of Solution %	Log. Viscosity 2% Solution	Time of Fall Seconds	Conc of Solution %	Log. Viscosity 2% Solution	Time of Flow Seconds
1·89	0·73	3·4	0·96	0·76	493
2·56	$\bar{1}\cdot77$	3·7	0·97	$\bar{1}\cdot81$	134
3·22	$\bar{1}\cdot66$	6·5	0·97	$\bar{1}\cdot69$	146
3·29	$\bar{1}\cdot25$	1·8	1·02	$\bar{1}\cdot21$	67·4
—	—	—	1·04	$\bar{2}\cdot40$	24·7

It will be seen that with the capillary tube viscometer the second and third results tabulated show a decrease in viscosity with an increase in time of flow. This is accounted for by the difference in the instrument constants of the two viscometers used. The last set of figures tabulated for the capillary tube viscometer show the results obtained for the lowest viscosity measured up to the present. It is probable that such a result would require to be corrected for the kinetic energy of the flowing solution. This correction could be avoided by increasing the concentration of the solution to about 2 per cent.

The dimensions of the viscometers in use as shown in the diagram are—

The reservoir is a specimen jar, 12 cm. high, 3 cm. diameter, 90 c.c. capacity, and approximately 50 c.c. of solution is used in each experiment. The bore of the side tube D is 0·7 cm. The capillary is 10 cm. long below the lower bulb and 1 mm. bore. The upper tube is 7 cm. long above the bulb and 0·5 cm. diameter. The main bulb is of capacity 10 c.c. between the marks. The lower bulb is to assist in preserving the head of the liquid and is approximately 1·5 c.c. capacity. All rubber joints are made with pressure tubing. To facilitate it being filled and emptied the side tube should be as wide as possible and the end below the rubber stopper cut off at an angle. The volume of the reservoir and side tube should be such that when the viscometer is inverted there is more than sufficient liquid present to fill the bulb tube and side tube.

The same reservoir is always used with any one bulb to avoid errors due to differences in diameter.

The viscometer is connected at B to a hydrogen supply and a high vacuum exhaust pump. The vessel containing the solution of cellulose material in cuprammonium is joined to the reservoir at A interposing if necessary a fritted glass filter of the coarsest grade obtainable. The hydrogen supply and pump are also connected up to the solution vessel at G. The solution vessel has had all air replaced by hydrogen during the preparation of the solution. The viscometer and filter are exhausted and washed with hydrogen twice through B to remove all air. They are again exhausted and screw clip B closed. Clip F on the solution vessel is opened and the viscometer reservoir filled through A,

washing the solution through with hydrogen by opening clip G, so filling the space in the viscometer above the liquid with hydrogen. Clip A is then closed, the viscometer disconnected at A and B and inverted. Pressure on the rubber tube ED forces the hydrogen out of the side tube which fills with the solution on releasing the pressure and the liquid flows up the bulb tube and fills the capillary and bulb. Clip C is then closed, the viscometer brought upright and placed in a thermostat. Pressure on the rubber tube between C and D removes all the liquid from the side tube up to the clip. Clip C is then opened and the solution allowed to flow through the capillary until the level is slightly below E. Exact adjustment is not necessary as the volume of the reservoir is comparatively large and a slight variation in the height of the solution at E will make little difference in the level of the liquid in the reservoir.

When the solution has come to the standard temperature the capillary is adjusted so that the lower end is just below the surface of the liquid in the reservoir. It has been found that more constant results are obtained when the end of the capillary can just be seen below the lower edge of the meniscus. If it is adjusted to touch the surface there appears to be an initial acceleration of flow due to surface tension drag which may make a difference of 4 to 5 seconds in a flow of 60 seconds. It is difficult to adjust the tube so that this effect is the same in every experiment. A slight error in adjustment is of less importance when the end of the capillary is fully immersed. After adjusting the capillary a slight pressure should be given to the rubber tube CE to remove any bubble trapped under the end of the capillary.

On opening clip C the solution flows through the capillary against the back pressure of the rising level in the reservoir and is timed between the marks. Inverting and filling the bulb can be repeated as many times as is desired. Repeated observations of the time of flow were not found to differ by more than 1 to 2 seconds in a flow of 60 to 200 seconds. The filling of the bulb and capillary can be done in less than one minute and, as the quantity of liquid present is comparatively large, the drop in temperature due to this short time of removal from the thermostat is very slight. At least 5 minutes is allowed after replacing the viscometer in the thermostat before making a second determination.

The only part of the viscometer not immersed in the water in the thermostat is the clip C and a short length of the rubber tube on each side of it and during most of the time this part of the tubing is filled only with hydrogen.

Assuming that the diameter of the reservoir is uniform throughout its length the level of the liquid is of no importance and the back pressure against the flow through the capillary is independent of the volume of solution present.

The viscometers were calibrated with a solution of cane sugar containing 40 g. sugar in 100 g. of solution and the instrument constants calculated, including the density of the cellulose-cuprammonium solutions in the constant. The density was assumed to be that of the cuprammonium[5] itself.

July 1930

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30—THE DETERMINATION OF SOLUBILITY NUMBER: A MICRO-METHOD FOR MEASURING THE EXTENT TO WHICH A CELLULOSIC MATERIAL HAS BEEN CHEMICALLY MODIFIED OR DEGRADED*

By C. R. Nodder
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The method described below is based on the experiments of Birtwell, Clibbens, and Geake[1] on the "solubility" of modified cotton cellulose in caustic soda solutions under stated conditions. The method adopted, employing 0·1 g. of material, has proved extraordinarily valuable as a routine test for the examination of defective materials, for control purposes at the bleach-green and for purposes of general research. It has been in constant use for two and a half years and from the results of some two thousand determinations there can be no doubt that it forms a reliable means of measuring the extent to which a linen or cotton material has been degraded by chemical attack; the greater the attack the higher the solubility number. The reliability of the method is confirmed by the curve obtained by Birtwell, Clibbens, and Geake (*loc. cit.*) relating the "solubility" of modified cotton cellulose materials in cold caustic soda solutions to viscosity in cuprammonium solution. A similar curve has been obtained with linen materials; this will be discussed in a separate paper.

DESCRIPTION OF METHOD

The material to be examined is first boiled for six hours under reflux in a 2% solution of caustic soda. It is then washed free from alkali and carefully dried. This preliminary boil is an essential part of the method, its object being to remove non-cellulosic impurities and cellulose degradation products soluble in boiling dilute caustic soda. The material is now cut into fine shreds. In the case of a cloth the method recommended by Birtwell, Clibbens and Geake is very satisfactory. For example, it is often convenient to cut from the cloth about ten strips, each measuring 1 in. by ¼ in., parallel to the warp or weft, and to cut very thin shreds (not more than 1 mm. wide) from these at an angle of 45° to warp and weft. The shreds are then broken down to a powder between finger and thumb. In the case of a yarn short lengths (less than 1 mm.) are cut off from the ends of a small bundle.

The air-dry powder (exactly 0·1 g.) is weighed into a test-tube provided with a ground-in glass stopper. A convenient size of tube is 5 in. × ⅝ in. The powder is tapped down into the bottom of the tube and caustic soda (10 *N*., 1 c.c.) is added, the drops being distributed as evenly as possible. Uniform wetting may be promoted by tapping the tube smartly with the finger-tips. If wetting is difficult stirring with a thin glass rod is desirable. As soon as possible the tube is immersed in a water bath maintained at

* The bulk of the matter included in this paper was published in April 1929 in the Linen Industry Research Association Memoirs, Nos. 58 and 59, entitled respectively "A Micro-Method for the Quantitative Examination of Modified Cellulose" and "Laundry Experiments with Linen Materials."

15° C.* After 15 minutes distilled water (4 c.c.) is added in order to dilute the caustic soda to 2 *N.* strength. The tube is replaced in the water-bath for the further period of one hour and shaken occasionally during that time. For filtering the solution from the undissolved residue a small fritted glass filter (Schott u. Gen., 30 a G3) is used, this being cut down to within 2 mm. of the disc. The filter is attached to the lower end of a 2 c.c. pipette by means of a suitable piece of thick-walled rubber tubing and immersed in the contents of the tube. The pipette is then filled by gentle suction from the water-pump. The filtered solution (2 c.c.) is run into a 100 c.c. flask and to it is added 10 c.c. of a half-normal solution of potassium dichromate containing 230 c.c. of concentrated sulphuric acid per litre. The flask is closed with a glass-pear stopper and *immersed* for one hour in a vigorously boiling water-bath, being shaken occasionally. The evaporation from the flask is not so great under these conditions as to necessitate the addition of water. After one hour the contents of the flask are cooled and titrated with decinormal ferrous ammonium sulphate, using potassium ferricyanide as an external indicator in the usual way. It is not difficult to avoid overshooting the end-point, but if this occurs a back-titration with decinormal potassium bichromate may be made. The half-normal acid bichromate solution (10 c.c.) is likewise titrated. Let a = number of c.c. of decinormal ferrous ammonium sulphate required by 10 c.c. of the half-normal acid dichromate and b = number of c c. of decinormal ferrous ammonium sulphate required by the contents of the flask.

Then *solubility number* $= 1{\cdot}688\ (a-b)$.

Three or four determinations may readily be made in one morning and three or four during the afternoon, the tests being started at intervals of about 15 minutes. The ferrous ammonium sulphate solution is made up fresh each day and the acid half-normal dichromate solution is checked each day against it.

Solubility number as defined above is the percentage of cellulose (calculated, not on the original weight of the sample, but on the weight of the material in the air-dry state after the preliminary boil in dilute caustic soda) which is dissolved by the caustic soda treatment at 15° C. under the conditions stated. The basing of the calculation on the air-dry weight is convenient and usually sufficiently accurate for routine control purposes and for the examination of defective goods, particularly (as is often the case) when the deductions may be based on a comparison of sound and defective materials analysed at the same time. In order, however, that a more strictly scientific meaning may, where necessary, be attached to the term solubility number the proviso is made that in the above definition the 0·1 g. of air-dry powdered material weighed into the test-tube is assumed to contain 7% of moisture. Where necessary the actual moisture content of a separate portion of the powder is determined and the calculation corrected accordingly. That is to say, solubility number $= 1{\cdot}688\ (a-b) \times \frac{100-7}{100-m}$ or $\frac{1{\cdot}57\ (a-b)}{100-m}$ where a and b have the same significance as above and m=moisture content of the powder.

* Vacuum flasks have been found very satisfactory for water-baths In hot weather the temperature of the tap-water may be above 15° C, in which case it may be cooled by the addition of ice or by dissolving in it a suitable salt, such as sodium sulphate. If sodium thiosulphate is used for this purpose care must be taken to avoid contamination of the contents of the tube.

The determination of moisture content may be made sufficiently accurately on 0·1 g. of the powder, using a very small weighing bottle. With this small quantity drying is very rapid.

PRACTICAL DETAILS

In the case of heavy or closely woven materials it is desirable to separate the warp and weft before giving the preliminary boil in 2% caustic soda, as otherwise the boil may not be sufficiently thorough. In extreme cases, particularly with grey or lightly bleached heavy materials, two 6-hour boils should be given. Proofed or specially finished materials may require additional preliminary treatment (for example, solvent extraction). Care must, of course, be taken that any such treatment is not such as may cause chemical damage to the material.

The fritted glass filters must be cleaned carefully after each experiment. This may be satisfactorily effected by drawing, first, caustic soda solution and secondly, distilled water through the filter and then warming for an hour or two with sulphuric acid and bichromate cleaning mixture. Instead of the 30a G3 filter a coarser-grain filter (30a G2) may be used. These give quicker filtration without affecting the result of the test. They are not at present listed in the maker's catalogue but may be obtained specially. The finer filters are, however, quite satisfactory, and if they are kept well cleaned the time required for filtration is rarely more than ten minutes even with materials of high solubility number.

If necessary the quantity of material taken for analysis may be reduced to less than 0·1 g. Thus 0·025 g. of a badly damaged material with a solubility number of 20 to 30 will give a titration difference ($a-b$) of some 3 to $4\frac{1}{2}$ c.c. If, before filtering, another 2 c.c. of water are added and 5 c.c. filtered off titration differences of 5–8 c.c. are obtained in the same circumstances. If this further quantity of water is added a further 0·8 c.c. of concentrated sulphuric acid should be added to the bichromate mixture. The calculation of solubility number is of course adjusted to take into account the smaller weight of material used and the different proportion of liquor which is filtered off. It is possible to obtain useful results even with 0·01 g. of material. For example, 0·01 g. of the powdered material (solubility number 14·0 by the normal method) was covered with 0·3 c.c. of 10 N. caustic soda which was later diluted by the addition of 1·2 c.c. water. The solution was filtered off through a small glass tube provided with a layer of asbestos into a 1 c.c. pipette. The filtrate (1 c.c.) was then treated with 5 c.c. of half-normal acid bichromate. The cellulose in the filtrate here corresponds with 0·0067 g. of the original powdered material as compared with 0·04 g. in the normal method (i.e. one-sixth).

$$\begin{aligned}\text{Titration difference} &= 1{\cdot}51 \text{ c.c.}\\ \text{Whence solubility number} &= 1{\cdot}51 \times 1{\cdot}688 \times 6.\\ &= 15{\cdot}3.\end{aligned}$$

It requires very great care to obtain results which are accurate to within less than 20% if this very small quantity is employed, but a result of this order of accuracy is often all that is required to give valuable information in many cases of the investigation of defective material.

DISCUSSION OF THE METHOD AND ITS APPLICATIONS

Duplicate and triplicate determinations made by the normal method (employing 0·1 g. of the powdered material) were in good agreement, as shown by the following results obtained with bleached linen damasks—

	Titration Readings a — b	Difference $a - b$	Solubility No. $1{\cdot}688\ (a - b)$
1	50·00 — 46·03	3·97	6·7
	50·00 — 45·87	4·13	6·98
2	50·00 — 46·78	3·22	5·44
	49·97 — 46·75	3·22	5·44
3	49·85 — 47·20	2·65	4·47
	49·85 — 47·30	2·55	4·31
	49·85 — 47·30	2·55	4·31
4	49·55 — 45·87	3·68	6·21
	49·55 — 45·92	3·63	6·13
	49·55 — 45·82	3·73	6·29

Blank determinations gave a mean titration difference of 0·05 c.c. which would correspond with solubility number of 0·084. A correction by this amount can be neglected for most purposes.

The effect of maintaining the temperature at 20° C. instead of 15° C. during the caustic soda treatment was examined in the case of 37 samples ranging from 5 to 45 in solubility number. The average ratio for the results obtained at 15° C. to those obtained at 20° C. was 116:100. No definite difference in the ratio was obtained at different parts of the range examined. Consequently if it is more convenient, as it may be in hot weather, the caustic soda treatment may be conducted at 20° C. and the result corrected by multiplying by 1·16.

The solubility number of flax cellulose prepared by the mildest possible treatments has been examined as follows—In one experiment flax fibre extracted from flax straw of normal ripeness by purely mechanical means was freed from non-fibrous tissue (epidermis, cortex, wood, etc.) by treatment with a hot soap solution, followed by thorough washing. After the preliminary boil in 2% caustic soda solution the solubility numbers obtained with two different qualities of flax were 2·3 and 2·6 respectively. Portions of another sample of similarly prepared fibre were boiled once, twice, and three times with 2% caustic soda solution for 6 hours each time. The solubility numbers obtained were 2·35, 2·03, and 2·26 respectively. It may be supposed that the extraction of non-cellulosic impurities (hemicelluloses, etc.) was not quite complete in the single boil while in the thrice-boiled material slight chemical attack during the boiling processes may have occurred.

In another experiment a normal grey dry-spun flax yarn (4½ lb.) was twice boiled for 4 hours with caustic soda solution under excess pressure (temperature 121° C.) in the absence of air, using 7½% and 5% of caustic soda on the weight of the yarn in the first and second boils respectively. After this treatment the yarn lost 25·2% in weight and had a solubility number of 2·9. Three other dry-spun yarns were twice boiled under excess pressure (temperature 121° C.) for 4 hours in caustic soda solution of 5° Tw., losing 26·3 to 28·5% in weight. After this treatment the solubility numbers were 2·89, 2·89, and 2·73.

From the above experiments, bearing in mind that, particularly in the case of normal grey yarns, boiling with dilute caustic soda solutions does not completely remove non-cellulosic impurities and that a slight amount of chemical attack probably occurs during the boils, it may be concluded that

the normal solubility number of unmodified flax cellulose is certainly not greater than 3·0 and probably not greater than 2·0. At the same time it is evident that thorough boiling in dilute caustic soda solutions in the absence of air raises the solubility number only very slightly, if at all. The lowest value so far observed is 1·7, obtained for a very thoroughly boiled Courtrai yarn.

That tendering by mechanical means does not increase the solubility number to a significant extent was shown by an experiment in which two qualities of bleached damask were hammered on an anvil until the material was quite rotten, falling to a powder when rubbed between the fingers. The solubility numbers were as follows—

	Before hammering	After hammering
1	4·3 ...	4·6
2	5·9 ...	6·2

The slight rise may be due to the rather finer state of division of the tendered material as obtained by cutting into shreds and rubbing between the fingers.

In order to determine whether attack by micro-organisms produces an increased solubility number a sample of linen tent duck which had suffered considerable diminution in strength owing to such attack was examined. The weft threads had lost about 40% in tensile strength and the warp threads (after a longer exposure to the attack of micro-organisms) about 60 per cent.

	Solubility Number	
	Before attack	After attack
Warp	3·85 ...	3·12
Weft	3·46 ...	3·88

It appears therefore that the solubility number (determined of course after the preliminary caustic soda boil) is only slightly, if at all, modified by attack by micro-organisms, even when a large decrease in strength is produced. This is in agreement with the results obtained by Searle[2] in experiments in which the viscosity in cuprammonium solution of materials tendered by attack by micro-organisms was determined. Further work is, however, desirable in order to determine whether this conclusion is true for attack by micro-organisms of all types (for example, iron and sulphur bacteria living alone or in association with other forms).

In examining materials that have been mercerised it should be remembered that this treatment may have produced a considerable reduction in the original solubility number.

In the case of materials which have become weakened after exposure to the weather (e.g., tent-cloth, awnings, etc.) it is often possible by the solubility number test to determine whether the loss in strength was caused by the action of light or by the growth of micro-organisms. It is important to bear in mind, however, that damage caused by light may be localised in those parts of the material which are near the exposed surface. Consequently in the case of a tent duck, for example, a solubility number of say 8·0 found for the material taken as a whole may mean that in the more exposed parts the solubility number is as high as 30·0, in which case the material would show very considerable weakness.

Numerous experiments have been made in order to determine what solubility numbers may be regarded as normal for various types of material at

different stages of bleaching. It is not proposed to describe these experiments in detail in this paper but it may be stated that a linen damask or sheeting if carefully bleached to a full white by normal processes has a solubility number of about 6·0. A solubility number greater than 8·0 in this class of material is highly undesirable from the point of view of resistance to wear, while a solubility number greater than 10·0 must be regarded as indicating definitely unsatisfactory bleaching. In the case of bleached yarns a decision as to the maximum desirable solubility number depends on the counts and quality of the yarn, the stage to which it is bleached, and the nature of the treatment it will receive after weaving, as well as on the use for which the material is intended. In general it may be said that the normal solubility number of a yarn of 35's leas bleached to the "three-quarter white" stage may be taken as 7·0, although it is possible to bleach yarn to this stage with a solubility number not greater than 4·0. At a lower stage of bleaching, or with finer yarn, a lower solubility number is desirable, while with coarser yarn a somewhat higher solubility number is often permissible.

An interesting relationship between solubility number and resistance to wear was observed in two laundry experiments with bleached damasks. Portions of two different webs of linen damask table-napkins, similar but not identical in quality, were bleached full-white by normal processes but the chemicking treatment was varied in order to produce different degrees of chemical attack. After bleaching the various samples were finished by normal beetling and calendering processes and cuttings measuring 2 ft. × 4 ft. were hemmed and repeatedly subjected to typical laundry treatments. The samples from the two webs were sent to two different laundries. The loss in weight was determined after every 20 washes. The table below shows the results—

Reference Number	*S* Solubility Number	$S^{0.53}$	*a* Loss in Weight per cent 40 Washes	*b* Loss in Weight per cent 60 Washes	*c* Loss in Weight per cent 50 Washes	$\frac{a}{S^{0.53}}$	$\frac{b}{S^{0.53}}$	$\frac{c}{S^{0.53}}$
2A	5·4	2·44	6·8	8·1	-	2·78	3·22	—
2B	6·3	2·65	7·2	8·6		2·72	3·24	
2C	7·9	2·99	8·3	9·6	-	2·78	3·21	-
2D	14·9	4·19	11·2	13·8	—	2·68	3·29	
7A	4·7	2·27	4·9	6·9	10·4	2·16	3·04	4·58
7B	6·8	2·76	5·6	8·8	12·7	2·03	3·19	4·60
7C	20·2	4·92	10·8	16·1	22·5	2·20	3·28	4·58

It will be seen that the loss in weight in repeated washes is roughly proportional to the square root of the solubility number, but more nearly proportional to $S^{0.53}$. Considerable experience with laundry experiments has shown that the loss in weight produced in repeated washes is a reliable guide as to the wearing qualities of a material. Consequently it appears that $S^{0.53}$ affords a valuable indication of wearing quality in so far as it is affected by the degree of degradation of the cellulose.

It is proposed to make further investigations along these lines.

In the case of materials which have been bleached full-white by a normal process, involving a thorough scour, the preliminary boil may sometimes be dispensed with if an approximate result is required. The possible influence of starch or other materials used in finishing must of course be borne in mind.

A low result will, however, always indicate little chemical damage even if the boil is omitted, but a high result will not in these circumstances necessarily indicate extensive chemical damage.

It has been found that normally bleached full-white linen materials, free from dressing or finishing materials, show very little difference in solubility number when the preliminary boil is omitted provided that the chemics used in bleaching were alkaline;[3] if, however, acid chemics are used an appreciably higher solubility number is usually obtained when the boil is omitted. For example—

	pH of Chemic (Buffered)	Solubility Number: With Preliminary Boil	Solubility Number: Without Preliminary Boil	Difference
Acetate buffer	3·9–4·0	3·9	4·7	+0·8
	4·4	3·9	4·6	+0·7
	5·0	3·8	4·5	+0·7
	5·4	3·7	4·6	+0·9
Phosphate buffer	5·7	4·2	5·2	+1·0
	6·0–6·1	4·9	5·4	+0·5
	7·1–7·0	5·6	5·6	0·0
	7·5–7·4	5·4	5·4	0·0
	8·0	4·8	4·8	0·0
	8·4–8·2	4·4	4·6	+0·2
Borate buffer	7·8–8·0	4·9	4·9	0·0
	8·6	4·3	4·3	0·0
	10·0	3·9	4·0	+0·1
	11·0	3·6	3·7	+0·1

In another experiment the following results were obtained—

	pH of Chemic (Buffered)	Solubility Number: With Preliminary Boil	Solubility Number: Without Preliminary Boil	Difference
Phosphate buffer	5·5–6·0	5·3	6·5	+1·2
	6·1–6·3	5·6	6·3	+0·7
	6·6–6·7	7·0	7·0	0·0
	7·1	7·4	7·0	−0·4
	7·5–7·6	7·0	6·8	−0·2
	8·0	6·2	6·3	+0·1
	8·5–8·3	6·1	5·4	−0·7
Borate buffer	7·6–7·4	6·4	6·0	+0·4
	8·5–8·6	5·2	5·2	0·0
	10·0	4·6	4·4	−0·2
	11·0	4·6	4·5	−0·1

The importance of the preliminary boil in cases of materials bleached to conserve weight, i.e. where hemicelluloses and other non-cellulosic impurities are retained on account of the mild scouring treatment employed, is shown by the following results obtained with three different materials—

	Solubility Number: With Preliminary Boil	Solubility Number: Without Preliminary Boil
1	6·6	11·1
2	6·9	11·6
3	7·1	11·1

With partly bleached yarns the difference is still more important. For example—

	Solubility Number: With Preliminary Boil	Solubility Number: Without Preliminary Boil
1—Cream yarn	3·8	11·0
2—½-White yarn	6·0	12·3
3—½-White yarn (overbleached)	7·8	13·6

The value of the solubility number test in the investigation of the causes of damage may be illustrated in general terms as follows—

(1) The test will show in practically every case whether damage or tendering was due to chemical attack (over-chemicking or other oxidative attack, action of acids, action of light, etc.) or to some other cause (i.e. mechanical action or attack by micro-organisms).

(2) In the case of damaged damasks, sheetings, towellings, etc., which have been repeatedly laundered a comparison of the solubility number of the sewing thread in the hem with that of the cloth will usually decide whether any general chemical damage was caused in bleaching or in laundering. It is nearly always possible to obtain from a sample submitted a sufficient weight of sewing thread for the determination.

(3) A comparison of the solubility number of the general cloth (or warp and weft separately) with that of the selvedge threads (commonly cotton) will often decide whether the yarn bleacher or the piece bleacher was responsible in cases of the over-bleaching of materials woven from partly bleached yarns and bleached further in the piece. It is sometimes possible to examine the solubility number of dyed cotton threads in coloured woven borders instead of that of the selvedge threads. If this is done discretion is necessary in interpreting the results as the dye may have an accelerating or retarding effect on the action of the chemic. Turkey red appears, however, to have no appreciable action in this way.

CONCLUSION

The solubility number method affords a simple and reliable means of estimating the extent to which a cellulosic material has been degraded by chemical attack.

The cuprammonium viscosity method is considerably more sensitive and reliable for indicating the initial stages of attack, that is when the solubility number is less than about 5·0 in the case of linen goods (log. viscosity 2% solution less than 1·0) or less than 2·0 or 3·0 in the case of cotton goods (log. viscosity 2% solution less than about 0·5).*

For general purposes, however, particularly with linen goods, the solubility number method is eminently suitable and everything considered, decidedly simpler than the viscosity method. When the degree of chemical attack is high (solubility number greater than 15·0 with linen goods or greater than 10·0 with cotton goods) it is more sensitive than the viscosity method.

It should be emphasised that the preliminary boil with 2% caustic soda solution is an essential part of the method. This treatment may cause a considerable loss in weight with a badly over-bleached material (removal of oxycellulose) or with a material that has not been thoroughly scoured, e.g. a typical half-white linen yarn (removal of hemicelluloses, etc.). The solubility number method depends on the estimation of the degree of degradation of the cellulose which remains after the preliminary boil. The method is, of course, in general, infinitely preferable to the determination of copper number as a means of estimating the degree of chemical attack. Copper number determinations are often valueless if the material has been treated

* For low and moderate degrees of degradation a linen material with the same solubility number as a cotton material shows a considerably higher viscosity. A well-bleached cotton material usually has a solubility number of between 1·0 and 2·0; a solubility number greater than 5·0 indicates serious chemical attack.

with hot alkaline solutions subsequent to the treatment which caused the attack or if the bleaching treatment (as in normal linen yarn bleaching) did not include a thorough scour. Thus a bleached linen yarn may have a copper number as high as 2·0 although the chemical attack on the cellulose may have been very small (solubility number about 3·0). Conversely a material woven from partly bleached yarns and bleached full-white in the piece may, if the yarns were over-bleached, show a low copper number (say 0·3) but a high solubility number (say 20·0).

Apart from its reliability the method has the merits that the quantity of material required for a determination is very small and that the apparatus and manipulation involved are very simple.

Most of the estimations on which this paper is based were carried out by Dr. R. W. Kinkead and Miss M. H. Preston. Numerous estimations which afford evidence for the reliability of the method were also made by Mr. T. Armstrong and Mr. A. S. Callaghan.

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[1] Birtwell, Clibbens, and Geake J Text Inst, 1928, **19**, T349
[2] Searle J Text Inst, 1929, **20**, T162, L I R A Memoir No 56, 1929
[3] Henderson and Nodder, L I R A Memoir No 62, 1929

May 1931

CORRIGENDUM

17—SOME RESULTS OF CROSS-SECTIONAL AREA AND CONTOUR MEASUREMENTS OF NEW ZEALAND ROMNEY AND CORRIEDALE WOOLS

By D. J. Sidey, B Agr., H D D.
(Wool Industries Research Association)

An error occurred in the above paper which appeared in the May issue of this Journal (T299-T304) and the correction is now published.

Page T303, Paragraph 2, Lines 7 and 8. The figures under *Corriedale* should read 1·199 and 1·201 respectively, and not as printed.

THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

31—THE FRICTIONAL PROPERTIES OF COTTON MATERIALS

By JOHN ALBERT MORROW, A.R.C.S., D.I.C.
(The British Cotton Industry Research Association)

I—INTRODUCTION AND SUMMARY

Most of the previous work on friction has been concerned with the measurement of properties likely to be of use to the engineer. A list of "coefficients of friction" is usually to be found in an engineering handbook, but the values are only approximate, and are intended to serve merely as rough guides to the relative magnitudes. For the engineer, no more is required, for the coefficient of friction is important only in bearings, where it must be small, and in brake linings, where it should be large.

The coefficient of friction is defined as the ratio between the force required to produce sliding of one surface on another (the tangential force) and the force holding the pair of surfaces together (the normal force). Experiments on the friction of pairs of hard solid substances have shown that this ratio is nearly constant, being independent of the pressure, the area of contact, and the rate of relative motion of the surfaces.

Very little is known about the actual cause of friction, but it is possibly due to some form of inter-molecular attraction. Before this friction, which is usually implied in the term "Coefficient of Friction," can be measured, it is necessary to have the surfaces under test in a highly polished state. Should they not be so, the property that is measured will be a complex mixture of the molecular friction, the resistance to tearing, imperfection of elasticity, and the extent of irregularity of the surfaces in question. The simple laws of friction, referred to above, then cease to hold, and the measured quantity will depend both on the pressure and the area, and may vary in quite a complicated way with any change in the surface conditions.

Probably for this reason very little work has been done on the frictional properties of textiles. Among the few references that are available may be mentioned some by Balls in his book "Studies of Quality in Cotton," and a paper on the measurement of yarn friction, by Krumme.[3] In addition to the rarity of smooth polished surfaces in textiles, the area and the regularity of the surfaces are affected by changes in the normal forces. If two cloths, for instance, are placed face to face, there will be a certain amount of interlocking of projecting hairs even with no normal force, whilst the area of contact is not at all definite. The area, however, would be expected to increase as the pressure became larger, and consequently the coefficient of friction could not be independent of the pressure unless it were also independent of the area.

The result of all these varying factors is to make it impossible to define the frictional coefficient as a simple physical constant for any given pair of substances. The most that can be done is to measure it under some standard

conditions, and then investigate the effect of all the factors that are likely to affect it. Actually, of course, this is the way in which all physical constants are measured, but in practice only those in which atmospheric conditions, previous history, etc., are not important are given as constants. An instance of the unsatisfactory state of our knowledge of friction is shown by the fact that, given the frictions of a pair A and B and another pair B and C, it is not possible to predict what will be the value for the pair A and C.

The coefficient of friction as defined above really includes three different quantities—the static, simple kinetic, and viscous frictions. In static friction the sliding force that is required to start the motion is measured, and this does not involve the speed. Simple kinetic friction is that usually found between dry polished solids in motion, and is independent of the speed once motion has started. Viscous friction is that most commonly met with in fluids, and increases with the first, second, or higher power of the speed, usually, however, with the first or second. In textiles all three frictions may be present together, so that the problem of measuring them is very complex.

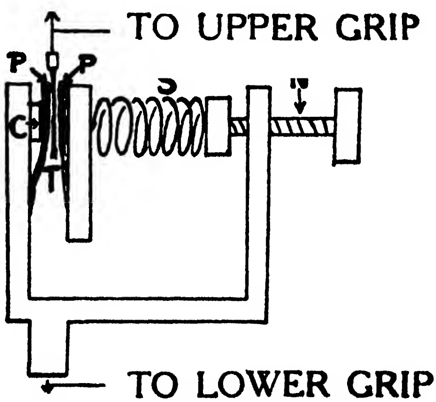


Fig 1

In this paper the results of a large number of measurements of hair and yarn friction are given, together with a summary of experiments on cloth friction. The paper is divided into three sections dealing with the friction of hair upon hair, and of yarn and cloth against various surfaces. The methods of measurement adopted are necessarily different, and the sections have therefore been kept separate.

As was expected, the friction has been found to be affected by many factors—the pressure, the area of contact, the relative speed, and the state of the surfaces, the temperature, and the relative humidity. When only the first two factors vary there is a general relationship of the form

$$F = mP + kA$$

between the tangential force F, the area of contact A, and the pressure P.

The measurement of hair friction has given indications that the coarser cottons have a larger friction coefficient, but the results obtained are not decisive. As with yarn friction, a large effect due to moisture has been found.

II—HAIR FRICTION

Hair friction has an important application in that the preparation and properties of a yarn may be expected to be largely influenced by it, but its measurement presents many difficulties. The first of these arises from the dependence of the friction on the speed and the pressure. Another difficulty lies in its dependence on the degree of parallelisation of the hairs. It is, therefore, extremely difficult to reproduce a result on different samples of the same cotton, and hence it has been found impossible to investigate directly the effect of altering the area of contact.

Balls[2] has described a method of measuring hair upon hair friction which involves the measurement of the strength of an untwisted roving. The method to be described in this paper attempts to define more precisely the pressure to which the hairs are subject, and is based upon a method described by Adderley.[1]

Experimental Method

The apparatus used is shown in Fig. 1. Two pads of hairs PP enclose between them a tuft T. The pads are prepared as described by Adderley, but the hairs are fastened at one end only. The tuft is simply a tuft of hairs attached at one end to a strip of cardboard by means of "Necol" cement, applied only to those parts of the hairs that are not in contact during the measurement.

A spring S, compressed by a screw N, applies a pressure which can be determined by measuring the length of the spring between the blocks. A rectangular packing piece C is placed behind one of the pads, and the tuft is made wider than this packing piece, which therefore determines the area of contact of pads and tuft. The whole apparatus is mounted in the grips of a single thread tester, the tuft being attached to the upper grip. The pads are then driven downwards at a constant rate, and the force necessary to withdraw the tuft from the pads is measured. The coefficient of friction is then found by the formula $\mu = \frac{1}{2}$ Force/Pressure, the factor $\frac{1}{2}$ being due to the fact that the pressure acts on two surfaces of the tuft.

Results and Discussion

Experiments with various materials under different pressures have shown that the coefficient of friction decreases as the pressure increases, and that the relationship between the force of extraction and the pressure can be represented by a straight line having a positive intercept on the force of extraction axis, as shown in Fig. 2. This was found to be usual with hair friction, and it may be attributable to the interlocking of hair convolutions.

The law for hair upon hair friction can be expressed by the equation

$$F = mP + kA$$

where F is the force of extraction, P is the normal force, A is the area of contact, and m and k are constants. If the simple laws of friction were obeyed and the coefficient of friction were independent of the area, k would be zero and the constant m would be the coefficient of friction.

The resistance of hairs to slipping can therefore be expressed as a force proportional to the normal force plus a small force proportional to the area of contact. A reasonable interpretation of the factor k is that it represents a

cohesion, which may be due to sticking of the waxy surfaces, or more probably to the interlocking of the hair convolutions. Consistent with the latter supposition is the small value of the force of extraction at zero pressure for rayon staple fibre (see Table 1 below); also it is greater with thick or much handled pads, and is unaffected by soda-boiling, which causes an increase in the coefficient of friction for higher pressures.

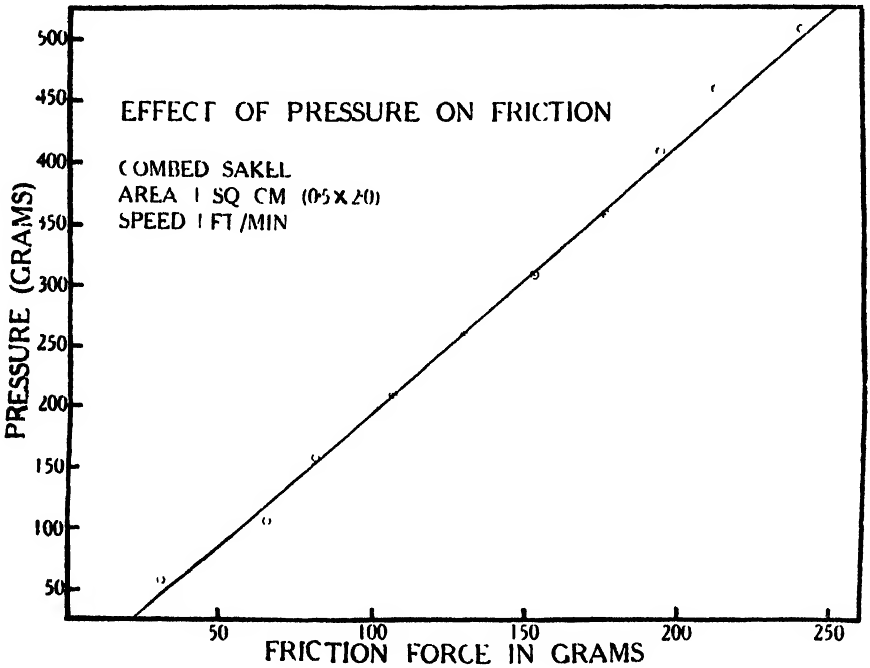


FIG. 2

The results of the various series of observations are summarised in Table I, which records for each material the value of the coefficient of friction observed at a pressure of 500 g. per sq. cm. and the extrapolated value of the force of extraction as the pressure approaches zero, the area of contact being maintained constant at 1 sq. cm.

Table I

Coefficients of Friction: Hairs upon Hairs

Material	Coefficient of Friction μ	Force of Extraction gm./cm.^{2} extrapolated to Zero Pressure
Sakel, air dry 70% R.H.	0·24	11
,, wet	0·32	19
Sea Island, raw	0·22	10
,, ,, soda-boiled	0·27	10
Texas, raw	0·24	23
,, soda-boiled	0·26	20
Vistra, staple fibre	0·30	0·5
Cotton (Sakel and Shan) against leather (roller covering)	both 0·3 approx.	—

Rayon staple fibre has about the same coefficient as cotton under a high pressure, but is far more slippery under zero pressure, probably because of the absence of convolutions. Scouring of cotton increases the coefficient, probably by removing some of the wax, which may act as a lubricant at high pressures, although at low pressures it may have a gumming effect. A wet sample gives a higher value than the same material dry, which is doubtless one of the reasons for the temporary increase of yarn strength at high humidities. There is an indication that the coarser cottons have larger values of the force of extraction at zero pressure, but the finer differences between varieties of raw cotton are obscured by erratic variations, which cannot yet be explained or eliminated. The rather crude loading arrangements of the single thread tester are not really suitable for this measurement, and further work would be necessary before the finer differences could be detected.

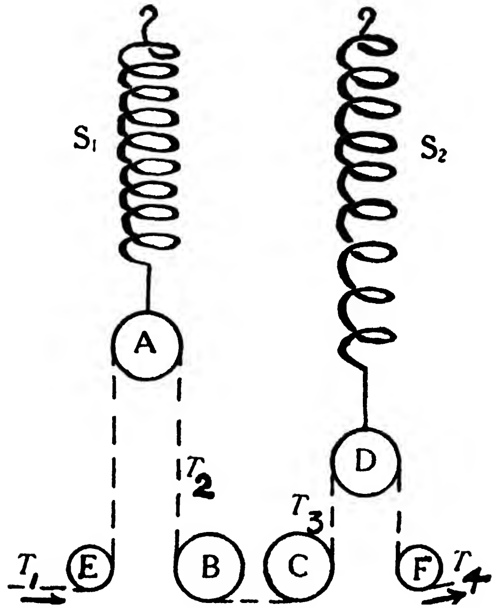


FIG. 3

III- YARN FRICTION

The frictional properties of yarn are of interest in many textile processes; they play an important part in the proper functioning of the sewing machine, and they considerably influence the knitting qualities of a yarn. The coefficient of friction is not directly responsible for the effects observed, however, but is of importance in that it is the main cause in determining the tensions in the threads. In the sewing machine, for instance, a safe working tension in the thread must not be exceeded, while at the same time a firm stitch must be produced. Owing to the large angles through which the thread turns in the sewing process very large variations in tension may be caused by changes in the surface friction of the yarn—changes which may, for example, be brought about by variations in the amount of lubrication along the thread.

In knitting, the friction is even more important. The spacing of successive rows of stitches is decided largely by the tension, and here again the tension may vary considerably as a result of changes in the frictional properties of the yarn. A heavily gassed yarn, for instance, may occasionally be impossible to knit for this reason. In winding it is often important that the tension should be neither too large, causing excessive breakages, nor too small, allowing weak places to pass on to subsequent processes. If the tension is controlled only by friction against guide rods, etc., it is liable to vary considerably. In this connection attention may be drawn to the higher frictional coefficient of rayon yarns, as compared with cotton. The experiments and instruments described below were designed mainly to investigate the effects on yarn friction of various changes in the conditions of measurement. The effects of speed, pressure, temperature, and moisture have been investigated, and in addition the effects of variations in the surface conditions (polishing, etc.), the change of friction consequent on running the yarn for a considerable time, and the effect of the radius of curvature of the test surface have been examined.

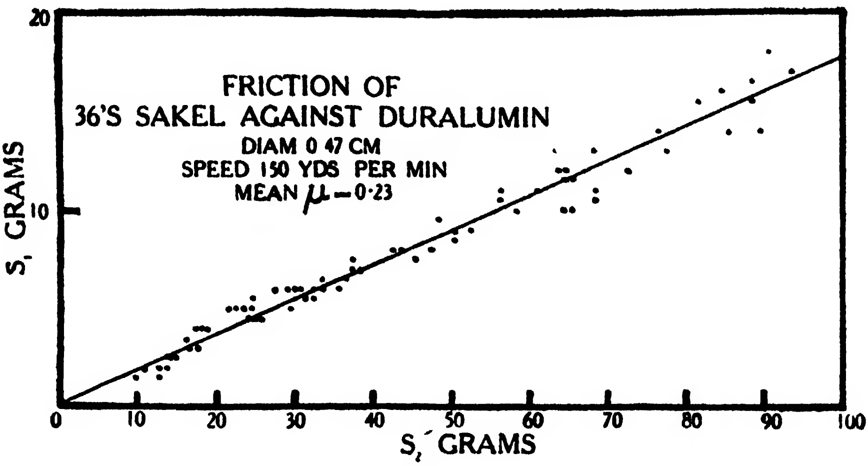


FIG 4

Experimental Methods

The first instrument used to measure the friction of yarns was an adaptation of the heavy type of single thread tester, but as this arrangement could be used only at low speeds, quite unlike most of those encountered in actual practice, it was found necessary to discard it. The second method that was tried allows of the yarn being run through the apparatus at the usual winding speeds. Two spring balances are arranged in the manner shown in Fig 3. The surface against which the friction is to be measured forms the four rollers, A, B, C, D, which are not free to rotate, so that the yarn slips over them, and exerts a downward force on the spring balances. Four rollers of the required material are necessary in order to avoid the use of pulleys on or between the spring balances, which would introduce an unknown amount of friction at their bearings. A preliminary drag (not shown on Fig. 3) applies an initial tension to the yarn, and this tension must remain steady during the measurement. A series of measurements was made with

different values of this initial tension, and the values of the spring balance readings (corrected for the weights of the rollers) are shown as S_1 and S_2 on Fig. 4.

It is known from the simple laws of friction that when a belt slides over a cylindrical surface

$$T_2/T_1=e^{\mu\phi}$$

where T_1 and T_2 are the entering and leaving tensions respectively, ϕ is the angle of contact of belt and clyinder, and μ is the coefficient of friction

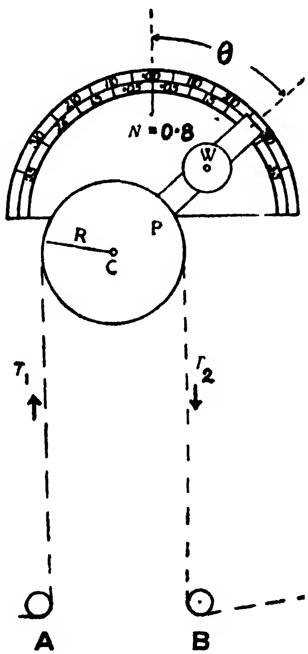


FIG 5

From this formula it can be shown that, in the arrangement adopted here,

$$S_2/S_1=e^{2\mu\phi}$$

where S_1 and S_2 are the corresponding readings on the two spring balances. If the simple laws of friction were accurately obeyed the graph obtained by plotting S_1 against S_2 would therefore be a straight line passing through the origin. The experimental results are plotted in Fig. 4, which shows that these laws are very nearly obeyed.

The apparatus just described suffers from the disadvantage that a very steady initial tension must be applied to the yarn, and also that four rollers of the necessary material are required for each surface against which the friction is to be measured. The instrument now to be described avoids these disadvantages, and has been found very convenient in use.

The diagram (Fig. 5) will explain the method of measurement. The yarn to be tested is passed over a pulley of the required surface

material; the pulley is pivoted at a point P away from its centre C, a counterweight W being used to bring the centre of gravity of the arrangement to the position of the pivot. The angle of contact of the yarn and pulley is fixed at 180° by means of the two small pulleys A and B.

Suppose the yarn before reaching the apparatus is at a tension T_1 and after leaving it is at a tension T_2. The pulley will turn through such an angle as will equalise the moments of these two tensions about the pivot. It can be shown that when the distance from the eccentric pulley to the small guide pulleys is large compared with the diameter of the eccentric pulley the position of equilibrium is defined by the equation

$$T_2/T_1 = \frac{1 + N\cdot\sin\theta}{1 - N\cdot\sin\theta}$$

where θ is the deflection of the pulley and N is the distance of the pivot from the centre, expressed in terms of the radius. From this it follows that

$$e^{\mu\phi} = \frac{1 + N\cdot\sin\theta}{1 - N\cdot\sin\theta}$$

where ϕ is the angle of contact of yarn and pulley which is here equal to π.

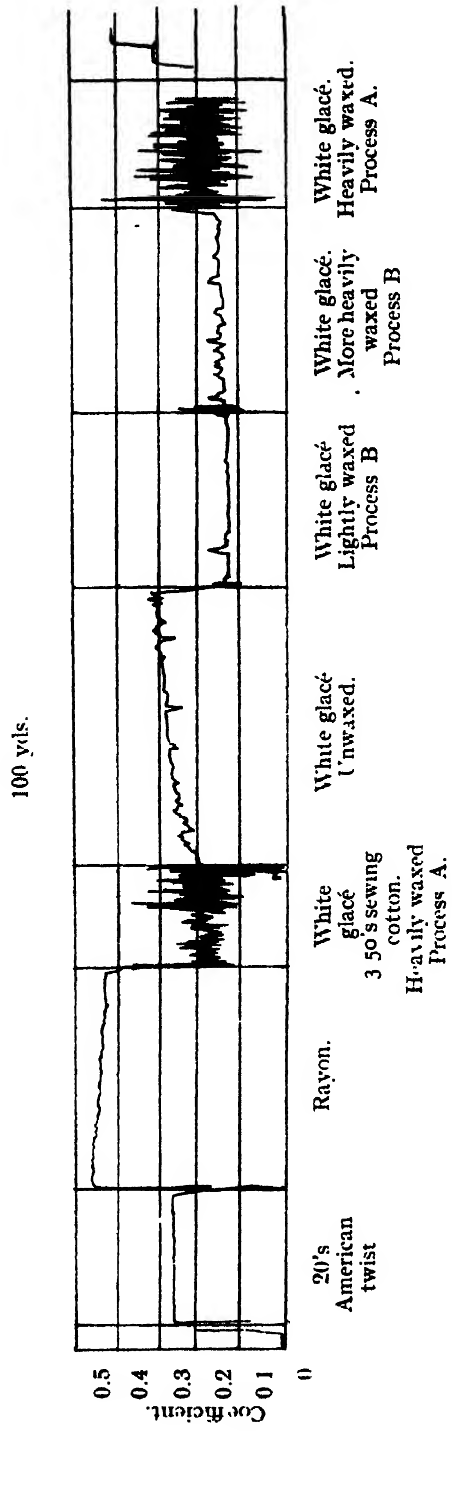
According to the above formula the deflection should depend only upon the coefficient of friction, and not upon the value of the tension T_1. In actual practice it is found that this deflection is not quite independent of T_1 but tends to decrease slightly as T_1 increases. This indicates an increase in the coefficient of friction with decreasing pressure, and resembles the effect already observed with hair friction. The effect with yarn on metal, however, is very small.

This instrument can also be used to measure static friction. A weight is hung on one end of a length of yarn which passes over the eccentric pulley, and the other end is fixed to a support in such a way that the angle of contact of yarn and pulley is 180°. If the pointer is then released at a high value of θ it will creep towards the zero and finally come to rest at the static friction value.

At any instant during its motion the value of μ indicated is that corresponding to the speed at which the yarn is slipping over the pulley surface, the motion being sufficiently slow to make acceleration forces negligible. This property has been made use of in the investigation of the effect of speed on yarn friction.

If the pointer is replaced by a pulley round which a thread is carried, the instrument may be used to actuate a pen, and in conjunction with a revolving drum continuous records of friction may be obtained. Some examples of such records are shown in Fig. 6. The first two records show that the friction of rayon against steel is greater than that of a grey cotton yarn. This is contrary to what might have been expected, but it has invariably been found for rayon on metal, and is of interest in connection with the winding of rayon yarns. The remaining records show the effect of waxing sewing cottons. It will be seen that waxing appreciably reduces the friction, that light waxing appears to impart all the benefit possible, and that the waxing may on occasion be very irregular.

A fourth method of measuring the friction of yarn was used in some experiments on the effect of temperature and humidity on friction, since it was necessary to have an apparatus that could be entirely enclosed in an



Comparison of Friction of Yarns against Steel.

Initial Tension, 30 grams.

Speed of winding, 65 yards per minute

FIG 6

air-tight box. The method adopted was that described by Krumme.[3] A closed loop of yarn is passed over a pulley, and a weight is hung on its lower end. When the pulley is rotated the weight is deflected to one side by an amount that depends only upon the ratio of the tensions in the two parts of the yarn, this ratio being decided, as mentioned above, by the value of μ. In use the pulley and loop of yarn were enclosed in an air-tight box, provided with a thermometer and means by which air of known humidity could be passed in. The different humidities were obtained by passing the air through wash-bottles containing various saturated solutions.

It must be pointed out that the results obtained from any method of friction measurement in which a closed loop of yarn is used are not reproducible, and the method is therefore available only for the investigation of the effects of different treatments on a given piece of yarn. If comparisons of different kinds of yarn are to be made it is essential to use the eccentric pulley tester and run the yarn through continuously.

Results and Discussion

It has already been mentioned that the frictional properties are of importance in determining the knitting qualities of a yarn. This is illustrated by the results of an investigation of the effect of gassing on the friction of knitting yarns against steel. These results were obtained on the eccentric pulley tester, the yarn running at a constant speed of 60 yards per minute; they are recorded in Table II. Slight gassing does not materially alter the friction coefficient, but if the gassing is severe a deposit appears to be formed on the yarn. Thus if a heavily gassed yarn is run over the steel pulley a great increase in friction occurs after a short time; this is presumably due to the transference of a substance from the surface of the yarn to that of the steel, for if a short length of ungassed yarn is run through the apparatus the friction of the heavily gassed yarn measured subsequently returns to its low value, and again increases to its high value after a short time of running.

Table II

Effect of Friction on Knitting

Speed for friction tests, approx. 60 yds. per min.

Times gassed	0	1	3	6
Coefficient of friction—At start	0·32	0·32	0·33	0·34
After 100 yds.	0·32	0·31	0·34	0·55
Courses per inch—At start	26·3	26·8	26·6	26·8
After 100 courses	27·2	26·5	27·0	33·6

The behaviour of the yarn on knitting agrees with the friction measurements. The ungassed and slightly gassed samples show very little difference, but the heavily gassed yarn shows effects indicating a progressively increasing tension. The effect, as with the coefficient of friction, is cumulative, and successive courses tend to get closer and closer together.

The effect of the speed of yarn on friction was examined by means of the eccentric pulley apparatus. For very low speeds the method described for the measurement of static friction was used; a series of readings was taken as the pointer moved towards the static friction value, and a curve of deflection against time was plotted from the readings. The velocity of motion at any instant was obtained from the slope of this curve at that instant, the diameter of the eccentric pulley being known, and hence the relation between the

coefficient of friction and the speed was determined. For higher speeds the yarn was run through the apparatus at a number of known speeds, and the friction reading taken at each. The results are illustrated in Fig. 7, which shows that the coefficient of friction increases progressively with the speed up to the highest speeds used.

As the readings at low speeds were taken on a short length of yarn, whilst at higher speeds the yarn was run continuously, the two curves of Fig. 7 are not strictly comparable.

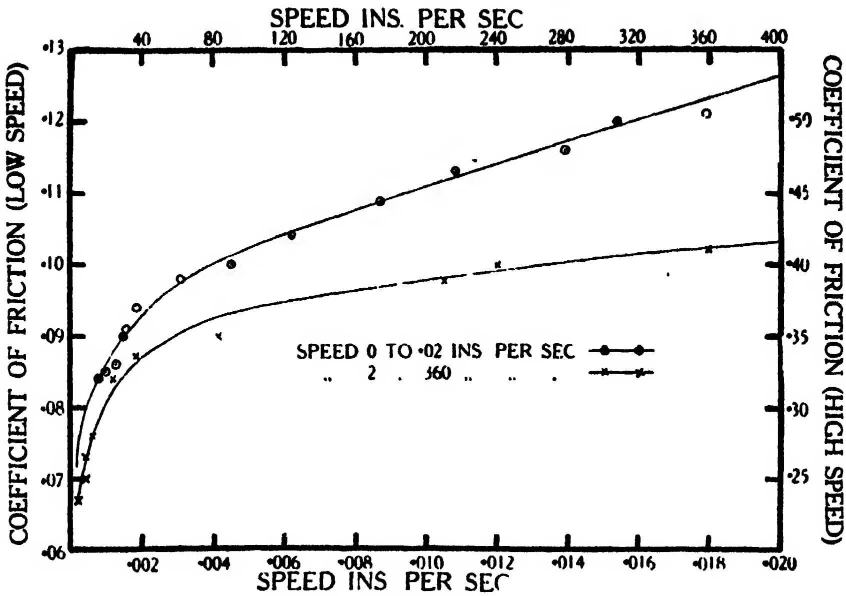


FIG. 7

It was observed early in these experiments that a high temperature appeared to have quite a large effect in reducing the friction. In order to confirm this observation the eccentric pulley apparatus was enclosed in a cupboard heated by electric radiator lamps; a closed loop of yarn was fitted to the instrument and was driven round by a small clockwork motor. Another loop of yarn, hung in the enclosure during the experiment, was weighed at intervals so that its regain could be determined. As the temperature was raised a considerable reduction in the coefficient of friction was observed, but as was to be expected the regain also decreased. It was therefore necessary to attempt to separate the effects of regain and temperature.

The effect of varying the regain at constant temperature was first examined. A number of cops were dried out in the oven, and water containing a wetting agent was added to them to give regains of from 0% up to 15%, and they were allowed to stand in closed bottles for some days before testing. Each cop was wound from its bottle through the eccentric pulley apparatus at a constant temperature of approximately 70° F., and after the friction had been measured the remainders of the cops were tested for regain by the usual method of weighing, drying, and reweighing. The results are given in Table III.

Table III

Effect of Moisture on the Friction of Yarn

Yarn 20's American twist, against steel.

Speed approx 65 yds./min. Temp. between 20° and 21° C.

Regain %	Friction μ		Regain %	Friction μ		Regain %	Friction μ
1·6	·242	...	5·1	·262	...	9·6	·297
1·8	·240	...	6·2	·270	...	10·0	·300
3·3	·250	...	7·2	·282	...	10·5	·317
4·0	·255	...	8·0	·289	..	10·5	·325
4·2	·252	...	8·6	·297	...	12·3	·342

From these results it is evident that the coefficient of friction increases considerably with increase in regain. This conclusion is supported by the results of another experiment in which Krumme's apparatus was used as already described, the humidity being controlled by passing into the box containing the apparatus air suitably humidified by means of saturated salt solutions; these results are shown in Table IV. They are, of course, not directly comparable with those in Table III, since they were determined on a closed loop of yarn, but again they show a pronounced increase in the coefficient of friction with increase of humidity and hence of regain.

Table IV

Effect of Relative Humidity on Friction

Relative Humidity %	Friction μ		Relative Humidity %	Friction μ		Relative Humidity %	Friction μ
0	·265	..	52	·321	..	86	·409
34	·289		70	·334		100	·436

A third experiment was undertaken to investigate the effect of temperature at constant regain, Krumme's apparatus again being used inside a box in which the atmospheric conditions could be controlled. The effect of temperature on the friction at two conditions of moisture was examined. In one of these the atmosphere was kept as dry as possible by supplying the box with air dried by passing through concentrated sulphuric acid, whilst in the other the air was kept moist by placing in the box a dish containing water. With the latter arrangement it was difficult to avoid films of moisture on the friction surfaces. Furthermore, the effect of friction in heating the yarn would cause it to be slightly drier while running. The temperature was controlled by varying the current in an electric heater element attached to the back of the box, outside it. The results are given in Table V.

Table V

Effect of Temperature on Yarn Friction

Yarn 20's American twist.

Speed approx 140 yds. per min, Krumme's apparatus.

Yarn Dry		Yarn Moist	
Temp. °C	Friction μ	Temp. °C.	Friction μ
20	0·34	19	0·43
55	0·31	50	0·44
86	0·29	87	0·33
		91	0·28
		100	0·25

It is evident from this table that temperature has a much greater effect on damp than on dry yarn. It will be noticed, however, that the "temperature" effect for the moist yarn is no greater than the humidity effect shown in Table IV, and since the arrangement adopted for keeping the yarn moist was necessarily crude, and unlikely to keep the yarn from drying considerably at high temperatures, it seems probable that the effect of temperature in reducing the coefficient of friction can be attributed mainly to its effect in drying the yarn, though the figures for the dry yarn suggest that there may be an additional small effect due possibly to the softening of the wax.

In order to separate the effects of temperature and regain more completely it would be necessary to use the eccentric pulley apparatus in an enclosure in which the temperature and humidity could be accurately controlled. In actual mill conditions, however, the relative humidity usually decreases as the temperature is raised, so that the yarn friction will decrease. This might tend to cause a slight reduction in the number of weaving breaks, though the effect would probably be masked by the reduction in yarn strength consequent on the lessened regain.

Table VI records some yarn frictions measured in the course of this work. Except where otherwise stated these were measured on the eccentric pulley tester, the yarn being run through continuously at the speed given.

Table VI
Miscellaneous Yarn Frictions

Initial tension, weight of two hanks, wherever possible.

Yarn	Surface	Speed	Friction μ
20's American twist	Steel	60 yds./min.	0·25 0·35*
,, ,,	,,	,, ,,	0·26†
,, ,,	,,	Static	0·06, approx
,, ,,	Duralumin	140 yds./min.	0·26
,, ,,	Polished boxwood	,, ,,	0·16
,, ,,	,, ,,	Static	0·20
20's–70's American	Ring traveller (steel)	15 yds./min.	0·27‡
38's American twist	Glass, 0·47 cm. diam.	150 yds./min.	0·20§
,, ,,	,, 0·62 cm. diam.	,, ,,	0·22§
36's Sakel	Duralumin, 0·8 cm. diam.	,, ,,	0·28§
,,	,, 1·4 cm. diam.	,, ,,	0·27§
2/50 Mercerised knitting	Glass, 0·62 cm. diam.	,, ,,	0·21§
,, ,,	,, 0·47 cm. diam.	,, ,,	0·17§
,, ,,	Steel	,, ,,	0·30
Rayon	Duralumin	,, ,,	0·45
Sized rayon	Wood	2–3 in./min.	0·21
,,	,,	Static	0·31
Rayon staple fibre			
Ungassed	Steel	140 yds./min.	0·34
Gassed	,,	,, ,,	0·39
Sewing thread—			
3/50 Unwaxed	,,	65 yds./min.	0·28
3/50 Waxed	,,	,, ,,	0·16

* Values vary with regain and temperature.
† At 70° F. and 70% R.H., conditions under which all experiments were conducted unless otherwise noted
‡ Measured on Krumme's apparatus.
§ These were obtained by the four-roller method.

An interesting result is that of the friction of sized rayon against wood. The static friction is here found to be considerably higher than the kinetic, a result that has never been obtained for the friction against a polished metal.

The effect of this is to cause the yarn to move over the roller in a series of jerks, the maximum and minimum readings being those of the static and kinetic frictions respectively, so that the additional tension applied by the friction roller is applied with a periodical variation.

IV—CLOTH FRICTION

There are difficulties, inherent in the characteristics of the surface of cloth, both in the measurement and in the interpretation of cloth friction. Suitable methods were developed for measuring the property under varied conditions; these are described below. The figures obtained seem to bear little relation to personal judgment of the feel of various fabrics and their state of finish, and the general conclusion from many and varied experiments is that resistance to sliding is not readily appreciated, or is overborne in personal judgments by other features. As there was little prospect of utilising the measurement for technical purposes, systematic experiments were discontinued, and are briefly described here mainly to support the above not unimportant conclusion and to save unnecessary repetition by other workers

A simple and common method of measuring frictional forces is to tilt an inclined plane till a body resting upon it begins to slide. The tangent of the critical "angle of rest" is the coefficient of friction of the two surfaces in contact. An instrument was made on this principle, which gives a measurement of the *static* friction, but the readings were very erratic, especially in measurements of friction between two similar cloth surfaces It was, however, possible to measure the slope at which motion just ceased, as the inclination was gradually diminished.

From observations of a cloth sliding on a similar cloth, a relation was obtained of the same form as for hair friction

$$F = mP + kA$$

In this instrument it was impossible to vary the speed, which was found to be an effective factor in yarn friction. A new machine was therefore made in which the relative motion of the two surfaces is under control, and which allows a direct and accurate measure of the tangential force between them (see photograph, Fig. 8). A strip of the cloth under test is carried on

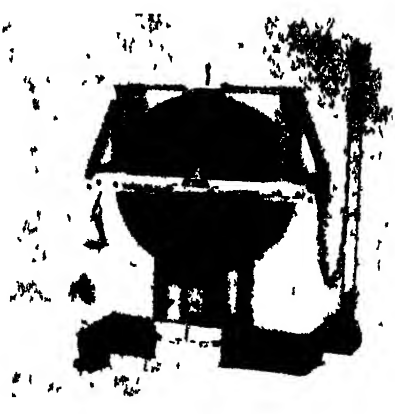


FIG 8

Kinetic Friction Tester, for cloth

the rim of a roller rotated at constant speed. The other friction surface is mounted on a block which rests on the roller rim under the desired load. Sideways or tangential movement of this block is constrained by a framework balanced about the same axis as that of the roller. The tangential force of friction is balanced by weights added to a pan on one side of the framework, fine adjustment being attained by a chain on the other side, on the principle of the "chainomatic balance."

No difficulty was experienced in accurately measuring the force of friction between a cloth specimen and any desired surface, over a range of pressure and speed, except the difficulty due to variations in that force itself. Many experiments were made to find conditions, and particularly a test surface that would give results for different surfaces bearing some relation to technical or aesthetic value. To avoid the confusion of a mass of figures of little individual significance, the experience so gained is summarised in descriptive form below.

A similar piece of cloth being used as test surface, it was found that fabrics with irregular surfaces bind on each other and will not slide smoothly. This is especially true of ridgy surfaces, a very common feature, as in repps. The friction immediately alters the state of the surface, making successive readings very erratic, and the result is unduly affected by adventitious previous treatment, such as folding or rubbing.

Chrome leather was tried for the test surface as an approximation to skin. The same jerky motion was observed to a less extent, also the disturbance of the surface by the test. Among fabrics which allowed smooth motion, the results were often insensitive to appreciable differences of feel. Significant differences could be observed on the same cloth with markedly different finish. For instance, the following values of μ were obtained. Plain weave grey 0·31, bleached 0·30, schreinered 0·26; twill (2/2), bleached 0·31, cold calender finish 0·30; five-shaft weft sateen, grey 0·45, bleached and mercerised 0·31, dyed, glazed and schreinered 0·26.

Against a polished steel surface, the motion was smooth and accurate reading was easy, without disturbance of the surface. All fabrics showed very much the same coefficient of friction (0·22). This is evidently the true molecular friction of cotton against steel and has little bearing on feel.

On the view that the fine surface irregularities predominate over true surface friction in subjective judgment, a test surface was sought which would be sensitive to these irregularities. Card clothing—with the wire pointing backwards—is such a surface which is constant and reproducible in character, and causes little disturbance of the surface of the cloth. Friction against this test surface proved reproducible, and distinguished sensitively between different fabrics. Thus a satin in the grey gave a figure 0·35; after a schreiner finish, 0·20. A finished satin with rayon warp gave 0·29 weft-way, 0·19 warp-way. It would be generally agreed that in both cases the lower figure corresponded to the smoother surface. On the other hand, a soft mercerised finish gave a higher value than a hard finish that felt harsher, whilst flannelettes gave values about 0·5, but velveteens 0·7 or more. Generally the test is more sensitive to hairiness than to the thready irregularities that determine the sensation "smooth" or "rough" which it is desired to measure.

To sum up, the measurement with a card clothing test surface may give interpretable figures in special cases within a limited range of similar fabrics.

The figures obtained on diverse fabrics, however, cannot be related to any one feature of technical import.

It was moreover found that whilst such descriptions as "smooth," "harsh," etc., may be applied as a result of handling a fabric, observers were very uncertain and divergent in judgment based on softly stroking a fabric laid flat on a table, that is, when nothing but sliding friction could be appreciated. When that feature is in question, reasonably good means of measuring it are available, if the result is interpreted according to the qualitative character of the surface—whether hairy or hard; but there seems little ground for supposing, even in the latter case, that sliding friction is of importance in deciding aesthetic value. Cases may occur, however, where it is of direct importance for a particular technical purpose. Thus, the writing surface of tracing cloth should be of a certain roughness to offer due resistance to a steel pen-point. After finding the most suitable friction by tests on good samples, the test might be used for the control of finishing processes and to grade deliveries.

Most of the observations have been made by Miss I. Evans.

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32—SOME TABLES SHOWING THE RELATION BETWEEN FIBRE LENGTH AND FIBRE THICKNESS IN VARIOUS WOOLS

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I—INTRODUCTION

Many observations have been made on the relationship between fibre length and fibre thickness. For the most part these have consisted in the comparison of these quantities in the form of mean figures for different locks of wool, for locks of wool from different areas of the body, for locks of wool from different sheep, and for locks of wool taken from individuals of different breeds. The results have been conflicting, some workers reporting a fairly high correlation, while others have stated that they can find little evidence of any such connection. There is no doubt that both types of result can be obtained, according to the material chosen for study.

The present work was undertaken with rather a different object in view. In a recent paper* I attempted to work out in detail a method for the determination of the mean fineness of samples of wool. This consisted essentially in the estimation of the number of centimetres of fibre that weighed a milligram. The method employed seemed to offer the chance of making observations on the relationship between fibre length and fibre thickness within single locks from a point of view rather different from that of most studies previously carried out. If a lock or a sample is taken and the length of all the fibres measured, these can be divided into length classes, and the mean fineness of the fibres in each length class separately determined. It is true that the individual fibre thicknesses are not measured, so that the figure for each length class is a mean figure only, but on the other hand this method allows one to obtain figures based upon the measurement of relatively very large numbers of fibres. The errors involved are very small. As complete locks are taken and the length of all fibres measured, and as subsequently all fibres are weighed, there are no sampling errors. The only errors involved are those of weighing and measuring, together with any errors introduced by the occasional breakage of fibres, and by any failure to divide off the lock completely and cleanly from the surrounding wool. These are all errors of determination, and with care can be reduced to comparatively small limits.

It will be recalled that in the paper on the measurement of fineness it was shown that it was possible to find locks included in the same comparatively small sample which possessed very different mean finenesses and lengths, and that in fact the difference in mean fineness occasionally found in the case of almost adjacent locks may be much greater than the difference in mean fineness between large and representative samples taken from quite different areas of the body. Serious doubt is raised as to how far the sorting of wool prior to manufacture does really depend upon mean fineness. Briefly, therefore, the present work arose out of an attempt to analyse these differences a little further. How far do fibres of the same length have the same thickness in nearly adjacent locks of very different mean thickness ? Is it not possible that the characteristic fineness-in-relation-to-length is an important attribute of wool ?

* Roberts, J. A. Fraser. "Fleece Analysis for Biological and Agricultural Purposes I—The Average Fineness of a Sample of Wool." J. Text. Inst., v. 21, pp. T127–T164, 1930

The results recorded in this paper supply only a partial answer to these questions, but nevertheless they are suggestive. It will also be seen that during the course of the work other considerations emerged, quite apart from the original purpose in mind when the work was undertaken, and that in fact the figures for various wools can be used for a variety of purposes. For this reason it may possibly be useful to other workers to have recorded some of the original observations, and I can only express the hope that the tables may be used by those investigating length and thickness in wool to supplement their own studies

II—METHODS

Samples were selected and prepared for analysis by washings with warm benzene and distilled water, precisely as was described in the previous paper Fibres were measured to the nearest half-centimetre, and accordingly a number of marked Petri dishes were laid out. Each fibre after measurement was placed in its appropriate dish. It was decided to use centimetre length groups, although the results of the measurements were recorded to the nearest half-centimetre. Accordingly, when the sample was finished the contents of the pairs of Petri dishes were rolled up together, rewashed, and the dry weight of each length group fraction determined as described in the previous paper.

The errors involved in this method are undoubtedly very small. Great care must be taken to separate off a complete lock of wool without breaking more than a very few fibres, and without pulling out an undue proportion from base or tip during the separation, but these are controllable errors. Breakage will inevitably occur, though again care in manipulation should reduce the amount to narrow limits. The effect of breakage is to increase the last group, which consists of very short fibres. It will also tend to affect all the groups slightly and in the same direction. The errors of length determination and errors of weighing should be small, though the weight of each fraction is the important limiting factor. Unless relatively enormous numbers of fibres are measured some groups will not contain very many fibres. An arbitrary limit of 4 mg. dry weight (corresponding to about 4·6 mg. as weighed in air) was chosen as the smallest weight to which significance could be attached. Figures based on smaller weights than this are shown in brackets in the tables. All these errors are errors of determination. There are no sampling errors, as all the fibres are measured and weighed, and as the purpose of the determination is to compare the fibres within the single lock.

The results have been calculated in terms of fineness stated as centimetres per milligram. This measure is inversely proportional to cross-sectional area. As in addition the lengths are determinate the figures given are inversely proportional to mean fibre weight.

III—THE VARIABILITY OF THICKNESS WITHIN A SINGLE LENGTH GROUP

The figure for the thickness of a single length group is an average figure only, and during analysis considerable differences between fibres of the same length can readily be perceived by eye. A rough estimate of this variability was obtained as follows—

A number of fibres of the same length were taken from a sample of the Border Leicester shoulder wool to which several of the tables refer. Using Tippett's* numbers a random sample was drawn and weighed. This random

* Tippett, L. H. C. "Random Sampling Numbers." Tracts for Computers, Cambridge University Press, London, 1927.

sample was then returned to the main group and a second drawing made, until the same number of fibres was withdrawn. The second lot was then weighed and the process repeated until a number of weighings for the same number of fibres had been obtained. The standard error of the weight per fibre was calculated and from this it was possible to obtain an estimate of the standard deviation of fibre weight for that particular length group (bearing in mind that the population was a finite one and using the full formula for the standard deviation).

The results were as follows—

Length cm.	Coefficient of Variability of Fibre Weight
23·7—23·3	±12·3
23·2—22·8	±14·5
22·7—22·3	±20·5
21·7—20·8	±20·7

It will be seen that except in the last instance half-centimetre length groups were used. The variability is very considerable, although as the longer length groups were selected it might be expected that the variability in these would be greater than in the case of the shorter length groups. It is clear that although over the greater portion of the curves there is a steady increase of thickness with each centimetre increase in length, this is a mean figure only, and that if the thicknesses of individual fibres were measured it would be found that the curves for successive length groups would overlap for the greater portion of their area. It will be noted that as the length is constant (within the small limits of the length group) the figures refer not only to weight per fibre but also to fibre thickness.

Further observations were made to determine how far weight per fibre varied in a complete lock of wool, in order to compare this variability with the variability for single length groups. The same Border Leicester sample was taken and fibres were withdrawn and placed in order in twenty Petri dishes until the sample was finished. The excess over twenty was omitted, so that each Petri dish at the end of the analysis contained the same number of fibres. The contents of the Petri dishes were weighed, and in the same way from the standard error was calculated an estimate of the standard deviation of fibre weight.

The results were as follows—

	Coefficient of Variability of Fibre Weight
Single lock	±39·0
Zoned sample. From 80 grams. 32 zones	±27·8
" " " ...	±34·9

The variability of fibre weight, therefore, within a single length group is very considerable as compared with the variability of fibre weight for complete locks of wool.

A Merino sample taken from the same shoulder sample as that referred to in Table XVI was treated in the same way, and the coefficient of variability of fibre weight was found to be ±34·1.

IV—THE GENERAL RELATION OF THICKNESS TO LENGTH

The figures for the mean fineness of the length groups, as shown in the tables for various wools, show a marked difference between successive centimetre length groups. The regularity of the curves over the greater portion of their length is striking. A few of the results are incorporated in the series

of curves. It will be noted how closely parallel some of the curves are, although they refer to entirely different wools, for example, the Australian Crossbred 50's and the Cape Merino 64's.

A feature of many wools is that the shorter length groups tend to show increased thickness, while the shortest of all show once again increased fineness. This feature is very well shown in the curves relating to the Border Leicester shoulder, Shropshire, and the Welsh Mountain, and it appears to be typical for a great many wools. The cause of this phenomenon is rather obscure. It might be accounted for by a proportion of fibres that grow to a certain length and then show very little increase, or conversely it might be due to the presence of fibres which started their growth late. On the other hand it might simply be an indication of the fact that more than one fibre type is present. This hypothesis is made more likely by the fact that the distribution of fibre lengths is quite commonly bimodal or trimodal.

In a recent paper* my colleagues Miss Norris and Mr. van Rensburg showed that the number of crimps per fibre was in general independent of fibre length. Some of their observations were made on the same fibres that are included in the present study. It is most interesting to note that those shorter length groups which show increased thickness, giving a pronounced kink in the curve, are also anomalous as regards their crimp number. For these length groups the average crimp number is less than for the other groups.

V—THICKNESS-IN-RELATION-TO-LENGTH AS A CHARACTERISTIC OF POSSIBLE IMPORTANCE

The original purpose in mind when this study was undertaken was to see whether in neighbouring locks of widely differing mean finenesses fibres of the same length might not have the same thickness, while in samples taken from different parts of the body there might be a considerable difference in this respect, although the mean lock finenesses might not be so very different. In the case of the Border Leicester sample to which frequent reference has been made, it does appear that the differences between length groups from coarse and fine locks are far less than the difference in their total mean fineness. For example, in Table XXI, if lock 1 and lock 3 are compared, it will be seen that the comparable length groups have very much the same fineness, while the mean finenesses are 80 and 93 cm. per mg. respectively, a very considerable difference. On the other hand, in certain cases locks with very much the same mean fineness may show large differences between the finenesses of comparable length groups. This is shown very well in Table XXIII, where two locks from a Welsh Mountain shoulder sample have mean finenesses of 117 and 121 cm. per mg. respectively, but fibres of 17 cm. length have a fineness in the one case of 86 cm. per mg., in the other 137.

As regards samples taken from different areas of the body, in Table XXI is shown a sample from the rump of the sheep (lock 5). Its mean fineness—69 cm. per mg.—does not differ quite so widely from lock 2, with a fineness of 79 cm. per mg., as does lock 2 from lock 3, both of which are taken from the shoulder. But whereas the differences in the case of corresponding length groups between lock 2 and lock 3 are quite small, the individual length groups differ very sharply in the case of both these samples from the fineness of the

* Norris, M. H., and van Rensburg, P J J. "Crimp in Wool as a Periodic Function of Time" J Text. Inst, v. 21, pp T481–T498, 1930.

length groups of the rump sample. In this case it is perfectly true that the fineness of individual length groups is a far better index of a difference as it would appear to the sorter than is the simple figure for mean fineness. The same remarks apply to the difference between the Lincoln rump sample shown in Table XXVI and the other samples shown in the same table, taken from the shoulder and side of the same sheep.

Is it not possible, therefore, that mean fineness alone may be a rather poor indication of what the sorter is doing when he sorts a fleece ? In the case of the Border Leicester shoulder sample all these locks would undoubtedly be included in the same sort, although their individual mean finenesses differ widely, but fibres of the same length tend to have approximately the same thickness in these various locks, so that in a sense when they are mixed it is not really a case of mixing quite different fibres. It is merely a case of mixing fibres of more or less the same kind, which are occurring in different proportions. On the other hand, if shoulder and britch locks are measured, fibres of the same length have very different mean finenesses, a difference that may be only poorly reflected in the mean finenesses for the complete locks.

VI—VARIABILITY WITHIN VERY SMALL LOCKS

Once again the analyses show that almost maximum variability in fibre characteristics is to be found within very small locks of only a few hundred fibres. This undoubtedly means that fibres of different characteristics are very well mixed on the skin. The figures quoted in the text above show that there is no reason to suppose that the coefficient of variability of fibre weight, as estimated from a single small lock, differs appreciably from the coefficient calculated from a zoned sample taken from a relatively large mass of wool.

VII—ACKNOWLEDGMENTS

I owe a great debt of gratitude for most painstaking and careful measurements to my assistants Miss M. Gurney, Miss D. Nicholson, and Miss M. Scheerer. I also wish to express my thanks to Miss M. H. Norris, who very kindly prepared the curves.

VIII—SUMMARY

(1) A number of samples of various kinds of wool were separated out into centimetre length groups and the fineness of each centimetre length group separately determined.

(2) Tables showing the relation between length and fineness in the lock are given.

(3) Observations are included on the results and the possible importance of the characteristic thickness-in-relation-to-length is noted.

A number of the wools examined were subsequently used by Miss M. H. Norris and Mr. P. J. J. van Rensburg for their observations on crimp, recorded in the Journal of the Textile Institute, v. 21, pp. T481-T498, 1930. In the case of measurements which refer to the same fibres a reference is given in each case to the corresponding table in their paper.

Figures in brackets refer to measurements based on dry weights of less than 4 milligrams.

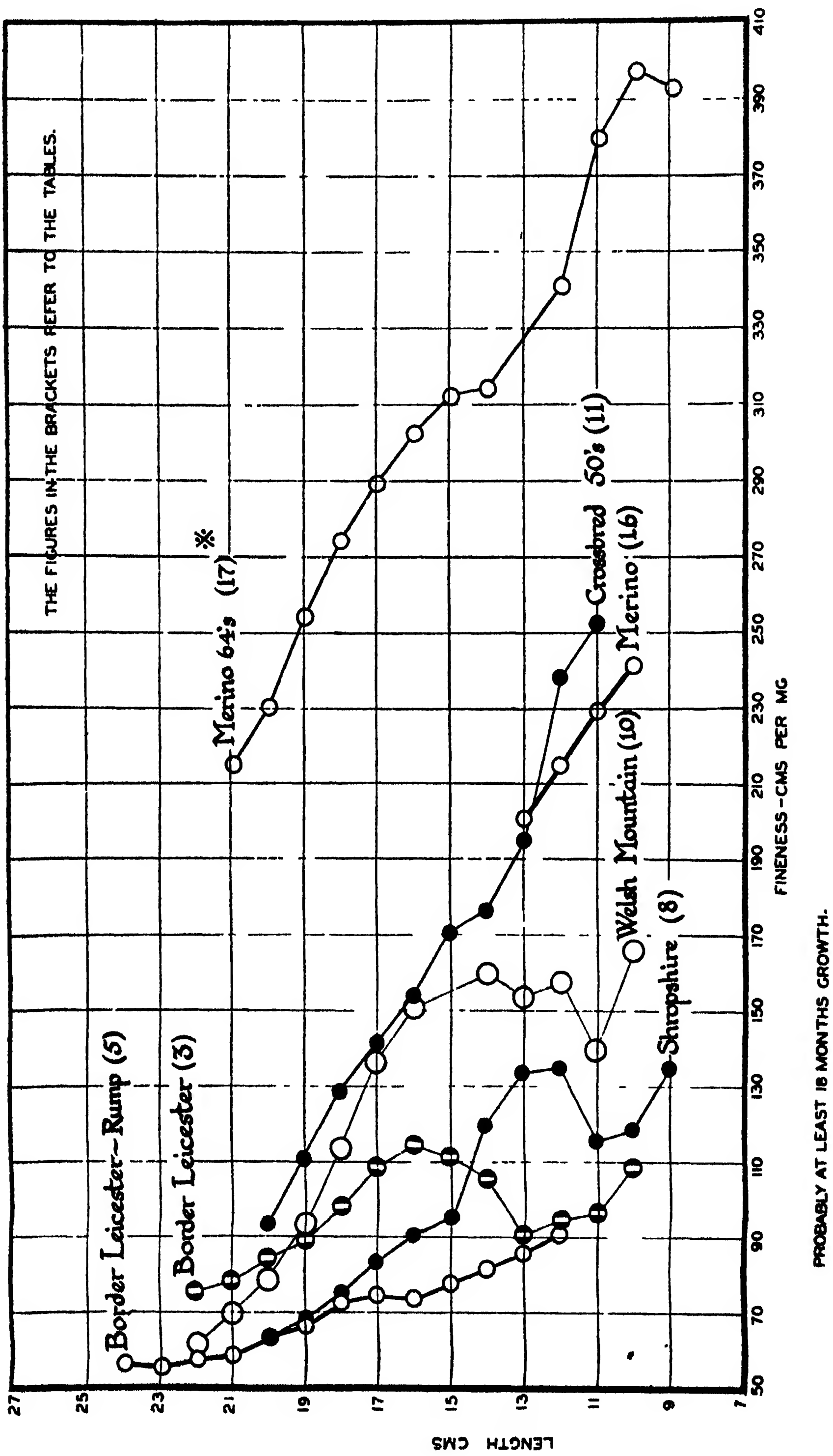

THE FIGURES IN THE BRACKETS REFER TO THE TABLES.
Merino 64's (17)*
Crossbred 50's (11)
Merino (16)
Welsh Mountain (10)
Shropshire (8)
Border Leicester—Rump (5)
Border Leicester (3)
FINENESS-CMS PER MG
LENGTH CMS
PROBABLY AT LEAST 18 MONTHS GROWTH.

Table I

Border Leicester. Shoulder A4. Single Lock. Mean Fineness 80 cm. per mg. Mean Length 19·4 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
28·25	1	6·0	55
27·25	11		
26·25	31	13·8	59
25·25	84	33·8	62
24·25	168	62·7	65
23·25	219	76·8	66
22·25	206	62·6	73
21·25	224	60·2	79
20·25	223	52·9	85
19·25	236	47·3	96
18·25	209	37·3	108
17·25	149	24·0	107
16·25	89	13·6	107
15·25	51	7·8	99
14·25	37	4·9	108
13·25	22	(2·9)	(102)
12·25	26	(3·1)	(103)
11·25	25	(3·4)	(83)
10·25	33	(3·7)	(92)
Less than 9·75 and broken	109	6·6	108
	2,153		

Table II

Border Leicester. Shoulder B3. Single Lock. Mean Fineness 79 cm. per mg. Mean Length 19·5 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
26·25	4	(1·4)	(73)
25·25	19	8·0	59
24·25	52	20·1	62
23·25	133	47·9	64
22·25	145	47·7	68
21·25	143	42·4	72
20·25	168	43·2	79
19·25	172	38·7	85
18·25	154	28·6	98
17·25	103	17·3	103
16·25	48	7·4	106
15·25	36	5·6	99
14·25	26		
13·25	21		
12·25	10	8·7	100
11·25	5		
10·25	4		
Less than 9·75 and broken	37	(2·3)	(92)
	1,280		

Table III

Border Leicester. Shoulder D4. Single Lock. Mean Fineness 93 cm. per mg. Mean Length 15·8 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
26·25	1		
25·25	2	20·3	73
24·25	12		
23·25	48		
22·25	159	46·1	76
21·25	242	65·0	79
20·25	219	52·3	85
19·25	176	37·4	90
18·25	198	36 5	99
17·25	185	29·3	109
16·25	147	20·9	115
15·25	104	14·1	112
14·25	92	12·4	106
13·25	86	12·5	91
12·25	131	16·9	95
11·25	117	13·5	97
10·25	86	8·1	109
Less than 9·75 and broken	343	15·8	135
	2,348		

Table IV

Border Leicester. Shoulder Sample. Square 16 cm. side. Zoned Samples. 32 Zones. Mean Fineness 81 cm. per mg. Mean Length 19·3 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
27·25	4	7·7	62
26·25	14		
25·25	43	18·4	59
24·25	75	28·3	64
23·25	146	50·0	68
22·25	183	57·9	70
21·25	208	57·0	78
20·25	199	48·7	83
19·25	195	41·0	91
18·25	167	31·7	96
17·25	159	26·5	104
16·25	86	13·6	103
15·25	78	11·0	108
14·25	49		
13·25	35		
12·25	23	16·7	103
11·25	20		
10·25	4		
Less than 9·75 and broken	45	(3·3)	(83)
	1,733		

Table V

Border Leicester. Rump. Mean Fineness 69 cm. per mg. Mean Length 17·8 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg
27·25	3		
26·25	1	4·4	59
25·25	6		
24·25	16	6·8	57
23·25	33	13·6	56
22·25	75	28·7	58
21·25	96	34·7	59
20·25	94	29·9	64
19·25	105	30·0	67
18·25	79	19·6	73
17·25	66	15·1	75
16·25	73	16·1	74
15·25	69	17·4	78
14·25	97	16·8	82
13·25	83	12·9	86
12·25	55	7·4	91
11·25	30	5·3	100
10·25	19		
Less than 9·75 and broken	35	(2·3)	(116)
	1,055		

Table VI

Cheviot. Shoulder. Single Lock. Mean Fineness 115 cm. per mg. Mean Length 16·8 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
25·25	3	(0·8)	—
24·25	18	4·9	89
23·25	77	21·0	85
22·25	159	38·2	93
21·25	165	36·0	98
20·25	214	41·4	105
19·25	209	36·9	109
18·25	238	37·1	117
17·25	242	34·4	121
16·25	254	30·7	134
15·25	188	21·0	137
14·25	120	12·4	139
13·25	77	6·9	147
12·25	53	5·1	128
11·25	42	(3·3)	(142)
10·25	39	(2·7)	(148
Less than 9·75 and broken	203	8·6	152
	2,301		

Table VII

Shropshire 50's (1). Single Lock. Mean Fineness 99 cm. per mg. Mean Length 12·6 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
21·25	5	7·6	72
20·25	22		
19·25	63	16·4	74
18·25	107	25·2	77
17·25	131	27·5	82
16·25	150	27·0	90
15·25	116	17·6	100
14·25	115	13·8	111
13·25	83	8·4	132
12·25	50	5·3	116
11·25	69	7·0	111
10·25	99	8·0	126
9·25	121	8·4	133
8·25	92	7·3	141
7·25	37		
Less than 6·75 and broken	171	5·6	116
	1,431		

Table VIII

Shropshire 50's (2). Single Lock. Mean Fineness 100 cm. per mg. Mean Length 13·1 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
22·25	3	7·7	58
21·25	18		
20·25	71	22·2	64
19·25	138	38·5	69
18·25	184	44·1	76
17·25	238	48·5	84
16·25	241	43·0	91
15·25	296	42·4	106
14·25	376	44·5	120
13·25	365	36·2	134
12·25	259	23·6	135
11·25	112	10·9	116
10·25	105	9·0	119
9·25	159	10·9	135
Less than 8·75 and broken	523	24·5	120
	3,088		

Table IX

Welsh Mountain. U30. Shoulder B4. Single Lock from opposite side to C3 of 256 sq. cm. sample. Mean Fineness 117 cm. per mg. Mean Length 12·2 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
19·25	23	6·5	68
18·25	50	12·6	72
17·25	79	15·8	86
16·25	108	18·7	94
15·25	151	20·1	115
14·25	149	16·6	128
13·25	191	18·7	135
12·25	238	21·0	139
11·25	160	13·4	135
10·25	117	7·9	153
9·25	49	5·9	157
8·25	57		
Less than 7·75 and broken	200	6·5	148
	1,572		

Table X

Welsh Mountain. U30. Shoulder C3. Single Lock from opposite side to D4 of 256 sq. cm. sample. Mean Fineness 121 cm. per mg. Mean Length 14·0 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
24·25	1	(3·2)	(59)
23·25	7		
22·25	35	12·6	62
21·25	75	22·7	70
20·25	77	19·6	79
19·25	125	25·6	94
18·25	143	22·9	114
17·25	166	20·9	137
16·25	165	17·8	151
15·25	134	12·3	166
14·25	137	12·2	160
13·25	139	12·0	154
12·25	102	7·9	158
11·25	63	5·0	140
10·25	86	5·3	166
9·25	89	6·4	192
8·25	49		
Less than 7·75 and broken	247	6·4	176
	1,840		

Table XI

Australian Crossbred 50's (1). Single Lock. Mean Fineness 162 cm. per mg. Mean Length 14·1 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
24·25	1	8·9	84
23·25	1		
22·25	6		
21·25	27		
20·25	58	12·4	94
19·25	175	30·2	111
18·25	209	29·7	129
17·25	207	25·1	142
16·25	166	17·5	154
15·25	193	17·3	170
14·25	157	12·6	177
13·25	177	12·0	195
12·25	185	9·5	238
11·25	312	14·2	247
10·25	201	9·4	274
9·25	55		
Less than 8·75 and broken	139	4·0	185
	2,269		

Table XII

Australian Crossbred 50's (2). Single Lock. Mean Fineness 137 cm. per mg. Mean Length 15·5 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
23·25	2	(3·2)	(73)
22·25	9		
21·25	31	7·6	86
20·25	85	18·5	93
19·25	174	31·3	107
18·25	284	46·3	112
17·25	305	41·6	126
16·25	300	35·6	137
15·25	238	22·6	161
14·25	232	18·4	180
13·25	214	13·9	205
12·25	158	8·4	231
11·25	94	4·5	237
10·25	32	(1·9)	(240)
9·25	13		
Less than 8·75 and broken	76	—	—
	2,247		

Table XIII

New Zealand 48's. Single Lock. Mean Fineness 111 cms. per mg.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
25·25	15	5·2	72
24·25	57	18·8	74
23·25	89	26·1	77
22·25	114	31·6	80
21·25	144	35·0	88
20·25	145	29·2	101
19·25	161	26·5	117
18·25	153	22·4	125
17·25	210	24·9	146
16·25	167	18·2	149
15·25	105	9·5	169
14·25	58	5·4	153
13·25	41	4·1	133
12·25	63	5·9	131
11·25	79	6·2	143
10·25	41	(2·8)	(151)
Less than 9·75 and broken	?	7·4	139
	1,642 + ?		

Norris and van Rensburg, Table V (2).

Table XIV

New Zealand 56's. Single Lock. Mean Fineness 92 cm. per mg. Mean Length 14·8 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
21·25	11	(3·0)	(78)
20·25	33	8·5	79
19·25	74	19·3	74
18·25	106	26·0	74
17·25	131	29·2	77
16·25	151	28·6	86
15·25	184	27·9	101
14·25	190	23·7	114
13·25	125	13·5	123
12·25	45	4·1	137
11·25	11	(1·5)	(86)
10·25	17	(2·1)	(85)
Less than 9·75 and broken	133	8·0	114
	1,211		

Norris and van Rensburg, Table V (2).

Table XV

Australian Matchings 58's. Single Lock. Mean Fineness 187 cm. per mg. Mean Length 13·0 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
18·25	1	(2·0)	(121)
17·25	13		
16·25	60	7·7	125
15·25	246	25·1	148
14·25	557	45·9	172
13·25	491	32·1	203
12·25	274	14·2	236
11·25	78	(3·9)	(229)
10·25	43	(2·0)	(223)
9·25	63	(2·3)	(260)
8·25	30	(1·2)	(213)
Less than 7·75 and broken	90	(1·5)	(222)
	1,946		

Norris and van Rensburg, Table I (10).

Table XVI

Australian Merino. Shoulder. Mean Fineness 221 cm. per mg. Mean Length 11·3 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
16·25	1		
15·25	1	(3·0)	(207)
14·25	42		
13·25	260	17·0	201
12·25	634	36·2	215
11·25	500	24·7	229
10·25	173	7·4	241
9·25	28		
8·25	19	(2·2)	(263)
7·25	23		
Less than 6·75 and broken	118	(1·7)	(302)
	1,799		

Table XVII

64's Cape. Single Lock. Mean Fineness 321 cm. per mg. Mean Length 14·1 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
22·25	18	(2·1)	(193)
21·25	77	7·6	215
20·25	129	11·1	235
19·25	181	13·7	254
18·25	197	13·1	274
17·25	281	16·7	289
16·25	321	16·3	320
15·25	251	11·6	332
14·25	154	6·6	334
13·25	83	(3·5)	(314)
12·25	130	4·7	341
11·25	249	7·3	380
10·25	205	5·3	397
9·25	202	4·8	393
Less than 8·75 and broken	323	5.5	385
	2,081		

NOTE—This wool is extremely long and probably represents 18 months' growth, perhaps more. Norris and van Rensburg, Table I (4).

Table XVIII

Lincoln Skin. Approximately 8 months' growth. Shoulder (1). Mean Fineness 75 cm. per mg. Mean Length 13·7 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
21·25	1	5·4	49
20·25	12		
19·25	34	13·8	47
18·25	95	33·1	52
17·25	138	41·7	57
16·25	111	28·4	63
15·25	158	32·4	74
14·25	130	22·0	84
13·25	130	18·4	93
12·25	98	11·5	105
11·25	70	6·7	119
10·25	52	4·2	128
Less than 9·75 and broken	205	10·6	149
	1,234		

Table XIX

Lincoln Skin. Approximately 8 months' growth. Shoulder (2).
Mean Fineness 64 cm. per mg. Mean Length 15·3 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
23·25	2	4·7	43
22·25	7		
21·25	25	12·5	42
20·25	73	33·0	45
19·25	128	50·5	49
18·25	162	57·0	52
17·25	137	38·4	61
16·25	159	36·5	71
15·25	175	32·1	83
14·25	138	22·2	89
13·25	93	12·9	95
12·25	67	7·2	115
11·25	43	7·9	131
10·25	53		
Less than 9·75 and broken	125	7·3	134
	1,387		

Table XX

Lincoln Skin. Approximately 8 months' growth. Britch.
Mean Fineness 56 cm. per mg. Mean Length 14·8 cm.

Length cm.	Frequency Fibres	Dry Weight mg.	Fineness cm. per mg.
23·25	2	6·7	38
22·25	9		
21·25	23	13·3	36
20·25	67	34·2	40
19·25	114	53·9	39
18·25	130	52·9	45
17·25	134	48·7	48
16·25	97	28·8	55
15·25	87	20·4	65
14·25	117	22·8	73
13·25	120	19·1	83
12·25	85	12·0	87
11·25	66	10·3	110
10·25	38		
Less than 9·75 and broken	156	8·1	149
	1,245		

Table XXI

Border Leicester

1, 2, 3 — Shoulder sample. Square 16 cm. side. Dissimular locks.
4—Same shoulder sample. Zoned, 32 zones.
5—Same sheep. Lock from rump.

Length, cm.	Fineness, cm. per mg. (1)	(2)	(3)	(4)	(5)
28·25	55				
27·25				62	59
26·25	59	(73)			
25·25	62	59	73	59	
24·25	65	62		64	57
23·25	66	64		68	56
22·25	73	68	76	70	58
21·25	79	72	79	78	59
20·25	85	79	85	83	64
19·25	96	85	90	91	67
18·25	108	98	99	96	73
17·25	107	103	109	104	75
16·25	107	106	115	103	74
15·25	99	99	112	108	78
14·25	108		106		82
13·25	(102)		91		86
12·25	(103)	100	95	103	91
11·25	(83)		97		100
10·25	(92)		109		
Less than 9·75 and broken	108	(92)	135	(83)	(116)
Mean fineness, cm. per mg.	80	79	93	81	69
Mean length, cm.	19·4	19·5	15·8	19·3	17·8

Summary of Tables I–V

Table XXII

Shropshire. 50's Matchings. Two Dissimilar Locks

Length, cm.	Fineness, cm. per mg. (1)	Fineness, cm. per mg. (2)
22·25	—	58
21·25	72	
20·25		64
19·25	74	69
18·25	77	76
17·25	82	84
16·25	90	91
15·25	100	106
14·25	111	120
13·25	132	134
12·25	116	135
11·25	111	116
10·25	126	119
9·25	133	135
8·25	141	
7·25		
Less than 8·75 and broken		120
Less than 6·75 and broken	116	
Mean fineness, cm. per mg.	99	100
Mean length, cm.	12·6	13·1

Summary of Tables VII and VIII.

Table XXIII

Welsh Mountain. Shoulder. Two Locks from opposite sides of square o 16 cm. side

Length, cm.	Fineness, cm. per mg. (1)	Fineness, cm. per mg. (2)
24·25		(59)
23·25	--	
22·25		62
21·25		70
20·25	..	79
19·25	68	94
18·25	72	114
17·25	86	137
16·25	94	151
15·25	115	166
14·25	128	160
13·25	135	154
12·25	139	158
11·25	135	140
10·25	153	166
9·25	157	192
8·25		
Less than 7·75 and broken	148	176
Mean fineness, cm. per mg.	117	121
Mean length, cm.	12·2	14·0

Summary of Tables IX and X.

Table XXIV

Australian Crossbred. 50's Matchings. Two Dissimilar Locks

Length, cm.	Fineness, cm. per mg. (1)	Fineness, cm. per mg. (2)
24·25	84	(73)
23·25		
22·25		
21·25		86
20·25	94	93
19·25	111	107
18·25	129	112
17·25	142	126
16·25	154	137
15·25	170	161
14·25	177	180
13·25	195	205
12·25	238	231
11·25	247	237
10·25	274	(240)
9·25		
Less than 8·75 and broken	185	—
Mean fineness, cm. per mg.	162	137
Mean length, cm.	14·1	15·5

Summary of Tables XI and XII.

Table XXV

Lincoln Skin. Approximately 8 months' growth. Shoulder. Locks 1 and 2

Length, cm.	Fineness, cm. per mg. (1)	Fineness, cm. per mg. (2)
23·25	-	43
22·25	-	
21·25	49	42
20·25		45
19·25	47	49
18·25	52	52
17·25	57	61
16·25	63	71
15·25	74	83
14·25	84	89
13·25	93	95
12·25	105	115
11·25	119	131
10·25	128	
Less than 9·75 and broken	149	134
Mean fineness, cm. per mg.	75	64
Mean length, cm.	13·7	15·3

Summary of Tables XVIII and XIX

Table XXVI

Lincoln Skin. Approximately 8 months' growth

1 - Shoulder (approximately).
2— Side, forward.
3— Side, towards back.
4 —Britch (approximately).

Length, cm.	Fineness, cm. per mg. (1)	(2)	(3)	(4)
23·25	40	34		38
22·25		39	(36)	
21·25	41	40	41	36
20·25	43	42	40	40
19·25	46	45	44	39
18·25	52	56	46	45
17·25	63	65	54	48
16·25	72	78	63	55
15·25	78	85	77	65
14·25	87	98	83	73
13·25	106	100	92	83
12·25	113	116	113	87
11·25	124	116	145	110
10·25				
Less than 9·75 and broken	(170)	166	182	149
Mean fineness, cm. per mg.	60	60	64	56

Nos. 1–3 not published in full. No. 4—Summary of Table XX.

33—MONTHLY WOOL GROWTH STUDIES, II; (a) HAMPSHIRE DOWN EWES; (b) CORRIEDALE EWES

By Robert H. Burns, M.S.

INTRODUCTION

In a former paper* the writer stated that monthly wool growth studies with five different breeds of sheep were started at the Wyoming Experiment Station in 1926, and carried on for the following four years up to and including 1930. The former paper gave the technique of measurement, which proved most satisfactory and gave the results of monthly wool growth in Rambouillet ewes. This paper, the second of the series, gives the results obtained in monthly wool growth studies in two breeds, Hampshire Down and Corriedale ewes.

The writer, now studying sheep breeding and fleece analysis at the Institute of Animal Genetics, University of Edinburgh, wishes to acknowledge his indebtedness to this Institute for the courtesies and suggestions extended to him during the preparation of this paper

EXPERIMENTAL PROCEDURE

The same procedure as followed with Rambouillet ewes, described in the former paper, was used for the other breeds. Four to six ewes were used during each year, the number depending on mortality and sales. No substitutions were made during the year, but each spring at shearing time young ewes were added to have as many different ages represented as possible Any ewes substituted for those sold, or deceased, were as nearly as possible of the same age as those which they replaced. Environmental conditions were the same as already reported for the Rambouillet ewes. Wool growth determinations were made by measuring the average length of clipping "sheaf" from the right mid-shoulder area of each sheep.

If the growth data for the Hampshire Down ewes is arranged in the form of a frequency distribution, the following figures are obtained—

Monthly Growth in tenths of an inch	Frequency		
2	42	Mean Monthly Growth	·33
3	92		
4	64	Probable Error of Mean	±·005
5	12		
6	1	Maximum Allowable Error (three times probable error of mean)	·02
7	3		
8	1		
Total ..	215		

A study of the large table of experimental results shows that there was a strong tendency for the wool of Hampshire ewes to grow uniformly throughout the year, for a comparison of the variation figures in the last column of the large table with the maximum allowable error (three times the probable error of the mean monthly growth) shows that during five months of the year the variation in average monthly wool growth is significantly different from the average monthly wool growth for the entire year, and during the other seven months making up the year the variation figure is not significant.

* J Text Inst, 1931, **22**, T98-T109

EXPERIMENTAL RESULTS

Hampshire Down Ewes

Monthly Wool Growth of Hampshire Down Ewes 1926–1930. Average Length (Three Readings) of Clipping "Sheaf" in Tenths of an Inch. Right Mid-Shoulder Area. Averages and Variation Figures in Hundredths of an Inch.

Year	1926 to 1927					1927 to 1928					1928 to 1929					1929 to 1930						Total	Number	Avg. Mo. Growth (in 0·01 inch units)	Variation* (in inch units)
Ear Tag Number	272	418	467	87880	87886	325	403	418	87880	87886	325	418	610	707	87880	325	418	610	724	802	87880				
Sampled June ...	4	8	7	6	7	3	3	5	2	2	3	4	3	3	3	4	4	4	3	3	3	84	21	40	+·07
July ...	5	7	5	5	4	3	3	4	2	2	2	3	4	3	2	4	sold	5	4	4	3	74	20	37	+·04
August ...	3	5	4	4	3	3	4	4	3	2	3	4	4	3	3	4		4	4	3	3	70	20	35	+·02
September	3	4	4	4	3	3	3	4	3	3	3	4	5	3	2	4		4	4	3	3	69	20	35	+·02
October ...	3	4	3	3	2	3	3	4	3	2	2	4	3	3	2	4		4	4	3	3	62	20	31	—·02
November	sold	3	4	3	2	4	4	4	4	sold	3	4	3	3	2	3		4	4	4‡	3	61	18	34	+·01
December ...		3	3	2	2	3	2	3	2		3	4	3	3	2	died		4	4	2	3	48	17	28	—·05
January ...		3	2	2	2	3	3	4	2		3	3	3	4	2			4	4	4‡	4	52	17	31	—·02
February ...		5	3	2	3	3	3	4	2		2	3	3	3	2			4	4	3	2	51	17	30	—·03
March ...		4	3	2	2	3	3	3	4		2	4	3	died	2			5	4	3	2	49	16	31	—·02
April ...		5	3	2	2	3	3	4	3		2	5	3		3			5	3	4	2	52	16	33	none
May ...		3	2	2	2	3	died	3	3		–	–	–		–	3†	4	4	4	3	3	39	13	30	—·03
Total Growth ...	18	54	43	37	34	37	34	46	33	11	28	42	37	28	25	26	8	51	46	39	34	711	—	—	—
No. Months Growth ...	5	12	12	12	12	12	11	12	12	5	11	11	11	9	11	7	2	12	12	12	12	—	215	—	—
Av. Monthly Growth (in 0·01 in. units)	36	45	36	31	28	31	31	38	28	22	25	38	34	31	23	37	40	43	38	33	28	—	—	33	—

* Variation of mean monthly growth by months from average monthly growth for the entire year.

‡ Five weeks growth.

The maximum growth occurred in June and the minimum in December.

† In 1929–30 all areas were cleared one month sooner than in former years

Maximum Variation in Monthly Wool Growth. Same Ewe; Same Month Different Years. Hampshire Down Ewes

Sampled	Readings in Tenths of an Inch												No. Months in Test	Total Variation (in 0·01 inch units).	No.	Average Variation inches
	June	July	Aug.	Sept	Oct.	Nov	Dec.	Jan.	Feb.	Mar.	Apr	May				
Ear Tag Number																
325	1	2	1	1	2	1	0	0	1	1	1	–	30	11	11	.10
418	4	4	1	0	0	1	1	1	2	1	1	1	37	17	12	.14
87880	4	3	1	2	1	2	1	2	0	2	1	1	47	20	12	.17

The average maximum variation in growth in the same ewe during the same month in different years varied from ·10 to ·17 of an inch, showing a strong tendency for the same individuals to grow wool uniformly throughout the year, and to grow about the same amount of wool during the same calendar months of different years.

WOOL GROWTH BY SEASONS

Hampshire Down Ewes

Two hundred and fifteen growth determinations from the Hampshire Down growth clipping samples over the four-year period, 1926–30, gave the following table of growth by seasons—

Season	Actual Wool Growth in inches	Per cent. of Yearly Growth
Spring—March, April, and May	1·03	26
Summer—June, July, and August	1·07	27
Fall—September, October, and November ...	·93	24
Winter—December, January, and February	·92	23
Total growth for the year	3·95	100

Again, as was the case with the Rambouillets at Wyoming, a remarkable uniformity of growth was maintained throughout the four seasons of the year. As would be expected, growth was less during those seasons when only dry feed was available and considerably more when green feed could be obtained.

In order that these figures might be compared directly with those reported by a number of investigators in Germany, an arrangement has been made of the data showing the wool growth of the first six months after shearing compared with the succeeding six months making up the year of growth. As before, there were 215 growth determinations over the four-year period.

	Actual Wool Growth in inches	Per cent. of Yearly Growth
First six months after shearing	2·12	54
Succeeding six months	1·83	46
Total growth for the year	3·95	100

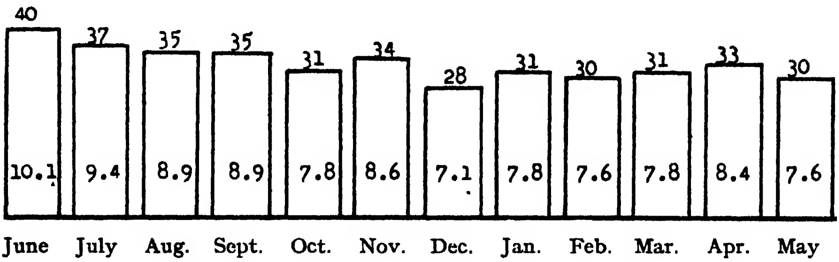
There was slightly more growth during the first six months after shearing.

CONCLUSIONS

Monthly Wool Growth in Hampshire Down Ewes. Growth in hundredths of an inch.
215 Monthly Wool Growth Determinations. 1926–1930.
Sheared on 19th May of each year.

Figures on top of columns represent growth in hundredths of an inch.

Figures within the columns represent each month's proportionate growth in per cent. of the total growth for the entire year.



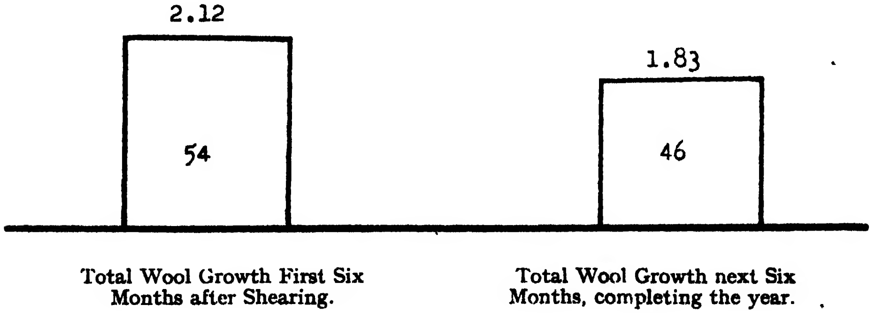
Hampshire Down ewe wool shows a tendency to grow uniformly during the different months of the year when the monthly variation is compared with an average figure for monthly wool growth during the entire year. The variations in wool growth from month to month, as shown in the chart, are slightly larger than was the case with Rambouillets (a maximum variation of 3·0% as compared to 2·3%). The Hampshire Down being a mutton type of sheep may possibly make more rapid and efficient use of the food it consumes, and consequently would tend to develop body and fleece characters more rapidly when green feed becomes available, than would be the case with the slower maturing Rambouillet of fine wool type.

If these data are arranged in two periods of six months' growth, they give information which can be compared directly with those results reported by a number of investigators in Germany and U.S.A.

Comparison of Wool Growth in Hampshire Down Ewes by Six-months' Periods beginning at Shearing Time.

Figures on top of columns give the total growth in inches.

Figures within the columns give the per cent. of yearly growth.



These results with Hampshire Down ewes confirm the results reported by the writer in an earlier paper already referred to.

EXPERIMENTAL RESULTS

Corriedale Ewes

Monthly Wool Growth of Corriedale Ewes 1926–1930. Average Length (Three Readings) of Clipping "Sheaf" in Tenths of an Inch. Right Mid-Shoulder Area. Averages and Variation Figures in Hundredths of an Inch

Year	1926 to 1927					1927 to 1928				1928 to 1929					1929 to 1930					Total	Number	Avg Mo Growth (in 0·01 inch units)	Variation* (in inch units).
Ear Tag Number ..	465	2101	2139	2175	2252	2101	2091	2139	2252	2091	2101	2139	2252	701	701	842	2091	2139	2252				
Sampled June ...	–	–	–	–	–	3	4	3	3	4	3	4	3	4	4	4	4	3	5	51	14	36	+·01
July ...	–	–	–	–	–	4	5	3	4	3	3	3	3	4	4	4	4	4	4	52	14	37	+·02
August .	–	–	–	–	–	4	4	4	4	3	died	3	3	3	5	5	5	4	5	52	13	40	+·03
September	5	5	4	4	8	4	4	4	4	5		3	4	4	5	6	5	4	5	83	18	46	+·11
October ..	4	4	3	5	7	4	4	3	3	4		3	3	3	4	5	4	4	4	71	18	39	+·04
November	4	4	4	3	3	5	5	3	3	4		4	3	3	4	5	5	4	3	69	18	38	+·03
December	3	3	3	4	3	3	5	3	3	4		3	2	3	4	5	5	3	3	62	18	34	—·01
January ...	3	2	2	2	2	3	5	3	3	2		2	2	2	3	5	4	3	4	52	18	29	—·06
February .	died	3	2	died	3	3	3	2	2	2		2	2	3	3	5	4	4	3	46	16	29	—·06
March .		3	5		4	2	2	3	2	3		3	2	2	3	4	3	3	2	46	16	29	—·06
April		3	3		3	3	4	4	2	3		2	2	2	4	4	5	3	3	50	16	31	—·04
May		3	4		3	2	3	3	2	–		–	–	–	2†	3	3	3	3	34	12	28	—·07
Total Growth	19	30	30	18	36	40	48	38	35	37	6	32	29	33	45	55	51	42	44	668	—	—	—
No Months Growth	5	9	9	5	9	12	12	12	12	11	2	11	11	11	12	12	12	12	12	—	191	—	—
Av Monthly Growth (in 0·01 in. units)	38	33	33	36	40	33	40	32	29	34	30	29	26	30	38	46	43	35	37	—	—	35	—

* Variation of mean monthly growth by months from average monthly growth for the entire year

The maximum growth occurred during September and the minimum during May

SUMMARY

(1) Hampshire Down ewe wool showed a tendency to grow uniformly throughout the year, as shown by monthly and seasonal growth, and the yearly growth did not vary markedly during the four years of the experiment.

(2) Hampshire Down ewe wool grew slightly more during the first six months after shearing (54%) than during the succeeding six months (46%), completing the year.

If the wool growth data for the Corriedale ewes is arranged into a frequency distribution, the following figures are obtained—

Monthly Growth in tenths of an inch		Frequency		
2	...	28	...	Mean Monthly Growth ·35
3	...	75		
4	...	59	...	Probable Error of Mean ±·005
5	...	26		
6	...	1	...	Maximum Allowable Error ·02
7	...	1	...	(three times probable error
8	...	1	...	of mean).
Total ...	...	191		

A study of the large table of experimental results shows that there was much more variation in wool growth in the Corriedale ewes than in any of the other breeds studied. A comparison of the variation figures in the last column of the large table with the maximum allowable error shows only three months when the variation was not significant, and nine months in which the variation exceeded the maximum allowable error. This would indicate that the Corriedale breed was more variable in wool growth from month to month than either the Rambouillet or Hampshire Down.

Maximum Variation in Monthly Wool Growth

Same Ewe; Same Month; Different Years. Corriedale Ewes

Sampled	Readings in Tenths of an Inch												No. Months in Test	Total Variation	No.	Avg. Variation inches
	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May				
Ear Tag Number																
701	0	0	2	1	1	1	1	1	0	1	2	–	23	10	11	·09
2091	0	2	2	1	0	1	1	3	2	1	2	0	35	15	12	·13
2101	0	2	–	1	0	1	0	1	0	1	0	1	23	7	11	·06
2139	1	1	1	1	1	1	0	1	2	2	2	1	44	14	12	·12
2252	2	1	3	4	4	0	1	2	1	2	1	1	44	22	12	·18

The average maximum variation in growth of wool on the same ewe during the same month in different years is about the same in the Corriedales as in the Hampshire Downs, varying from ·06 to ·18 of an inch. Thus in Corriedales, as in Hampshires and Rambouillets, there is a tendency for the same individuals to grow the same amount of wool during the same months of different years.

WOOL GROWTH BY SEASONS
Corriedale Ewes

One hundred and ninety-one determinations from the Corriedale growth clipping samples over the four-year period, gave the following table of growth by seasons—

Season	Actual Wool Growth in inches	Per cent. of Yearly Growth
Spring—March, April, and May	·95	23
Summer—June, July, and August	1·23	29
Fall—September, October, and November ...	1·11	27
Winter—December, January, and February	·87	21
Total growth for the year	4·16	100

There is more variation in the Corriedales than in either the Hampshires or Rambouillets, the maximum difference in percentage of growth amounting to 4% in the Hampshires and Rambouillets, and to 8% in the Corriedales.

If these figures are arranged so as to compare the growth the first six months after shearing with the succeeding six months making up the year, one obtains the following figures. As before, there were 191 growth determinations.

	Actual Wool Growth in inches	Per cent. of Yearly Growth
First six months after shearing	2·36	57
Succeeding six months	1·80	43
Total growth for the year	4·16	100

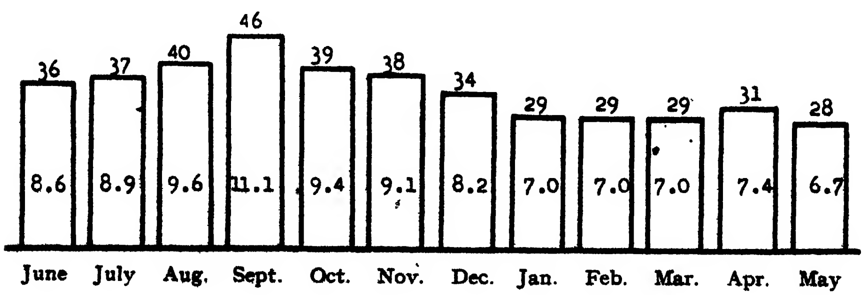
The Corriedale ewes showed the greatest growth during the first six months after shearing (57%) of any of the breeds under study (Hampshires, 54%, and Rambouillets, 52%).

CONCLUSIONS

Monthly Wool Growth in Corriedale Ewes. Growth in hundredths of an inch.
191 Monthly Growth Determinations. 1926–1930.
Sheared on 4th May of each year.

Figures on top of columns represent growth in hundredths of an inch.

Figures within the columns represent each month's proportionate growth in per cent. of the total growth for the entire year.

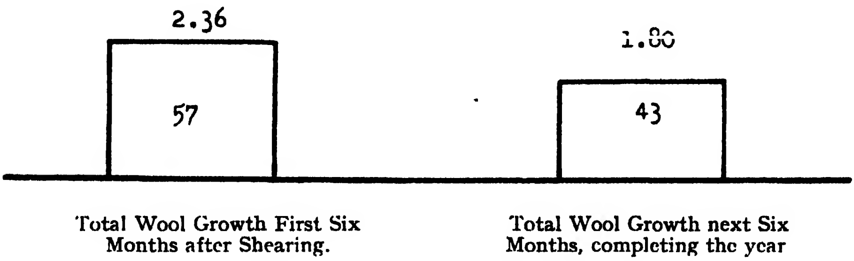


Corriedale ewe wool did not grow uniformly during the year, being much more variable in monthly and seasonal wool growth than either the Rambouillet or Hampshire Down. Although there was a decline in wool growth beginning in December it did not become dormant during the last two months completing the year, as suggested by Zorn, Heyne, Stohman, Gartner, and Rohde.

Comparison of Wool Growth in Corriedale Ewes by Six-months' Periods, beginning at Shearing Time.

Figures on top of column give total growth in inches.

Figures within columns give the per cent of yearly growth attained during the six-month period



The Corriedale ewes' wool growth was 10% greater during the first six months' period than during the succeeding six months completing the year. The first six months of wool growth from the Corriedale ewes represented 57% of the growth for the entire year. This figure is 10% under the figure reported by Zorn, Heyne, Stohman, Gartner, and Rohde.

The wool growth studies made at the Wyoming Experiment Station with Rambouillet, Hampshire, and Corriedale ewes support the view that wool has an inherent tendency to grow uniformly throughout the year, and oppose the view that wool grows by the law of diminishing returns and attains two-thirds of its yearly length during the first six months after shearing, and then gradually diminishes until during the last two months completing the year there is no appreciable growth.

The tendency of wool to grow uniformly is affected by environmental factors which give dissimilar reactions in different breeds and even in individuals within the breed. The results obtained at Wyoming agree with the results reported by Hackedorn and Sotola using Rambouillets, and Nordmeyer using Mutton-Merinos (Merinofleischschaf).

SUMMARY OF MONTHLY WOOL GROWTH RESULTS USING RAMBOUILLET, HAMPSHIRE DOWN, AND CORRIEDALE EWES

(1) Monthly wool growth in Rambouillet and Hampshire Down ewes showed a tendency to be uniform throughout the year, as shown by monthly and seasonal growth, and the total yearly wool growth tended to be the same during the four years of the experiment.

(2) Wool grows slightly more (average difference 9%) during the first six months after shearing than during the succeeding six months completing the year.

(3) The Corriedale ewes showed much more variability in monthly and seasonal wool growth than the Rambouillets and Hampshires.

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CORRIGENDUM

30—THE DETERMINATION OF SOLUBILITY NUMBER: A MICRO-METHOD FOR MEASURING THE EXTENT TO WHICH A CELLULOSIC MATERIAL HAS BEEN CHEMICALLY MODIFIED OR DEGRADED

By C. R. Nodder
(The Linen Industry Research Association).

An error occurred in this paper which appeared in the August issue of the Journal (T416-T424). The second paragraph of the Conclusion (p. T423) should read as follows, the words to be changed being printed in italics.

"The cuprammonium viscosity method is considerably more sensitive for indicating the initial stages of attack, that is, when the solubility number is less than 5·0 in the case of linen goods (log. viscosity 2% solution *greater* than 1·0) or less than 2 or 3 in the case of cotton goods (log. viscosity 2% solution *greater* than about 0·5)."

THE JOURNAL OF THE
TEXTILE INSTITUTE
TRANSACTIONS

34—THE DETERMINATION OF TOTAL SIZE OR FILLING IN COTTON GOODS

By DOUGLAS A. CLIBBENS, Ph.D., and ARTHUR GEAKE, Ph.D.
(British Cotton Industry Research Association)

INTRODUCTION

The technique described in text books for the determination of the total amount of size on a grey cloth or yarn is simple, but the interpretation of the results obtained demands critical treatment. In spite of this, no critical examination of methods for size analysis has ever been recorded in the scientific or technical literature. Simple directions for the determination of the size content of a cotton cloth were first given by Thomson[3] in 1877 and these directions, sometimes slightly modified, have been repeated at intervals in text-books down to the present time, but no published investigation of the reliability of Thomson's method has been found.

This paper contains a critical examination of some methods for total size analysis in grey cotton, as a result of which a standard procedure is recommended (page T472). The same procedure can be used for determining the proportion of filling in finished material.

GENERAL DESCRIPTION OF THE INVESTIGATION AND ITS RESULTS

1—The Nature of the Problem

In order to determine the total amount of size in a sample of grey cloth, it is submitted to some process that removes the size—called for convenience a "desizing" process—and the consequent loss in the weight of the cloth is measured. If the size removal were complete, and if the desizing process removed nothing but size constituents, this loss of weight would evidently give an accurate measure of the amount of total size in the cloth. These conditions—complete and exclusive removal of size constituents—are never realised in practice, and every determination of total size with a claim to accuracy involves a correcting calculation which takes account of this fact. The essential problem is to discover a method of desizing which most nearly fulfils the ideal conditions, and for which the correcting calculation can be made with the maximum accuracy. The simplest effective method of desizing naturally depends on the nature and weight of the size; from cloth containing lightly sized warp yarns, for example weighted 10% with a pure starch size, simple boiling with water would remove practically the whole of the size together with a small amount of material from the cotton, for which a sufficiently accurate correction could be made in calculating the result. This paper is concerned, however, with general procedures which can contend, not only with light sizing, but also with yarns carrying up to 100% or more of size containing large quantities of starch, China

clay, tallow or other common size softener, and magnesium and zinc chlorides or other salts employed in size mixings.

2—The Two Methods of Desizing Examined

Thomson[8] used the following method for desizing—The grey cloth is thoroughly washed in cold water, boiled for one hour in 1% caustic soda solution, again washed in cold water, boiled for one hour in 1% hydrochloric acid solution, washed, and finally boiled for an hour in water. Thomson assumed that this process would remove all the sizing constituents, but he realised that it would also remove some of the natural constituents of the cotton, and that the loss of weight would, on this account, be greater than the actual amount of size in the cloth. A correction must therefore be applied in calculating the result, namely, the loss of weight which the cotton would have sustained had it been entirely devoid of size. This correction will be called the "desizing blank," though it was described by Thomson as "mineral matter," presumably under the mistaken impression that the loss of weight suffered by unsized cotton on boiling with alkali and acid was due, in the main, to the removal of mineral substances. The magnitude of the correction, or desizing blank, is given by Thomson as 1% of the weight of the size-free cotton.

It is evidently possible to vary the details of Thomson's method, for example, with respect to the strength of acid and alkali, and the temperature at which they are used, but there is very little evidence to show in what direction such variations could usefully be made. The only modification of the method that might be expected to afford a definite advantage consists in extracting the cloth with an organic solvent as a preliminary to the washing and boiling treatments, and this is recommended in some text-books.

No evidence was adduced by Thomson in support of the accuracy of his desizing blank. The assumption that the size constituents can be removed by his process is justified with respect to starch and the sizing salts, but without further evidence it is not justified with respect to fats and China clay; any removal of the latter is effected only by the mechanical action of the washing and boiling processes. The inclusion of a treatment with an organic fat solvent in the desizing process removes any doubt as to the complete extraction of the fatty ingredients.

Another method of desizing was used by Lecomber and Probert[1] for analytical purposes, and it consists in removing the fats by solvent extraction, the starch by malt extract, and the salts by thorough washing. In this, which will be called the malting method, reliance must again be placed upon purely mechanical action during washing for the removal of China clay, if the method is used for the analysis of weighted goods. It remains to consider the extent to which such reliance is justifiable, and to determine the magnitude of the desizing blank for the malting method.

3—Summary of Experimental Work

A definite procedure based on Thomson's method of analysis was adopted for the purpose of this work. It will be called the scouring method, and is described in detail on page T469. A detailed procedure was also selected for analysis made by the malting method (page T470). The scouring and malting methods in the forms described were examined and compared with the following results—

(*a*) Observations were made of the losses of weight incurred by eighteen *unsized* yarns of various qualities when submitted to the scouring and the malting treatments. These desizing blanks represent the accurate corrections that should be applied in size analyses on cloths containing the cottons in question. In the routine analysis of cloth there is generally no information available as to the quality of cotton employed, and no samples of the unsized warps to serve as a control. It is then necessary to assume an average value for the desizing blank. For the six American and four Egyptian cottons examined the average blank was 4·6% of the dry weight of the treated cotton in the scouring, and 3·2% in the malting method. These figures were used to correct total size analyses in cases where no unsized warp yarn was available as a control. The values given by the Egyptian cottons were slightly higher than those given by American cottons, and the maximum range of variation was from 3·5% to 5·1% in the scouring, and from 2·6% to 3·5% in the malting method. The desizing correction of 1% recommended by Thomson himself is far from correct, and introduces an average error of at least 3·5% in size analyses by his method on cloths made from American and Egyptian cottons; this statement is based on the fact that the original method described by Thomson is, if anything, more drastic in its action on the grey cotton than the modified form here examined, since it prescribes both a higher scouring temperature and a higher concentration of acid.

For other growths, the desizing blanks are much more variable. Native Indian cottons, in particular, yield very high values; for example, a Surat cotton gave 7·2% by the scouring and 5·1% by the malting method. The assumption of the average blanks given above would lead to errors of 2·6% and 1·9% for the two methods of size analysis respectively, applied to cloth containing this cotton, whilst the correction used by Thomson would result in an error of at least 6·2 per cent. American strains of cotton developed in India (Punjab American) yield the normal blanks characteristic of American cotton. The ratio between the malting blank and the scouring blank for the same cotton is always very near to 0·7, being almost independent of the cotton, whether it gives relatively low blanks like the American cottons or high blanks like the native Indian varieties. The range of variation in the malting blanks is therefore only seven-tenths of that in the scouring blanks, and the absolute errors unavoidably introduced in size analysis by the variability of the raw material are therefore smaller in the malting than in the scouring method.

(*b*) The two desizing methods have been examined with respect to the completeness with which they effect the removal of China clay. Incomplete removal of clay does not actually affect the accuracy of the analyses in the forms described on page T469, since an additional operation is introduced after desizing. This consists in burning the desized cloth and weighing the ash, which, apart from a small correction, is due to clay remaining in the cloth after desizing. This operation does not form a part of the Thomson method as originally described, and it greatly increases the time necessary for an analysis. Until any method has been tested in this way it is not possible, however, to decide whether the additional operation is necessary, or whether a sufficiently complete removal of clay is secured during desizing.

As already explained, the elimination of clay is accomplished purely by the mechanical working of the cloth during washing and boiling. The

extent of this removal must therefore be expected to vary with the precise details of the desizing treatments, and the conclusions now to be recorded refer to the procedures described on pages T469 and T470. The scouring process is found to be much less efficient in removing clay than the malting, in spite of the fact that it includes an equally energetic mechanical treatment of the cloth. The assumption that the scouring method effects practically complete removal of clay is not justified, and with cloths containing 10% to 20% of clay, errors in total size analysis as great as 3% may result from such a false assumption. In order to obtain accurate results with filled cloths by the scouring method it is therefore necessary to include the ashing operation. In the malting method of desizing, the amount of clay that escapes removal is usually less than half of one per cent, and no great error would be caused by neglecting it and omitting the final ashing process.

(*c*) The removal of fats by the scouring method (without solvent extraction) has been examined, and it has been shown that errors of 1% in total size analysis may arise owing to the incomplete removal of fatty materials by this method.

(*d*) It is unfortunately impossible to obtain sized yarn or cloth of which the total size content is so exactly known that the material can serve as a control on the accuracy of analytical methods. By means of a series of variously sized cloths a comparison has been made, however, between the results obtained by the two different methods of analysis. The cloths were normal trade samples, and none of the unsized warps was available for control purposes; the desizing blanks used were, therefore, the average values already recorded, and account was taken in both methods of the amount of China clay which remained in the cloths after desizing. The agreement between the results given by the two methods was satisfactory, but in most cases the malting method gave a slightly higher size content than the scouring. This was undoubtedly due in part to the relatively inefficient removal of fat by the scouring process. For ten cloths examined, varying in size content from 5% to 30% (on the weight of the cloth), the average difference between the results given by the two methods of analysis was 0·3%, the malting method giving the higher figure.

4—The Standard Malting Method for Total Size Analysis

From the experimental work summarised in the previous paragraphs, the conclusion is drawn that for a general standard procedure the malting method is to be preferred to the scouring, since (1) the removal of clay and fats is more efficient, and (2) the blank corrections show a smaller variation between different growths of cotton. It is possible that the use of solvent extraction combined with the scouring procedure would result, not only in better removal of fats, but also in better removal of clay as a direct consequence.

In the particular form of the malting method adopted for the experimental work described, the cloth, after solvent extraction and washing, was allowed to lie overnight in malt extract in order to remove the starch. Subsequent work was directed towards a modification of this method to make it as convenient and rapid as possible for routine purposes, and to improve still further the removal of clay. It has been found that the action of the malt extract, if combined with mechanical treatment of the material, can be reduced to fifteen minutes without sacrificing anything in the completeness of removal of starch, and with an improvement in the removal of clay.

A standard method for routine purposes is fully described on page T472, which consists in extraction for one hour with chloroform, a short impregnation with "diastafor" solution, and further washing in hot water. This method has been tested on the range of cloths previously used, and has been found to give as accurate results as the longer procedure. The mean blank correction adopted is 3 per cent.

In order to secure results of equal accuracy by the scouring method it would be necessary—in the general case—to combine this, either with solvent extraction, or subsequent ashing of the desized cloth, or both, and the analysis would then occupy much more time than the standard malting method outlined above. The Thomson method in the simple form given by its author might yield fairly good results in many cases owing to a compensation of errors. Thus, the use of a desizing blank of 1% as recommended by Thomson himself gives a value for the total size content which, on account of the erroneous blank alone, would be on the average at least 3·5% too high. If the Thomson desizing method applied to medium and heavy sized fabrics fails to remove some 2% to 5% of the size ingredients (fats and clays), the total size would, on this account alone, be reported 2% to 5% low, so that the false blank and the incomplete removal of size ingredients would result in partially self-compensating errors. This compensation does not occur in the analysis of pure, lightly sized goods by the original Thomson method, and the errors are then very great if a desizing blank of 1% is used.

EXPERIMENTAL DETAILS

Methods of Desizing

(1) *Scouring Method*—A piece of cloth in its loom state was weighed in its air-dry condition (approximately five grams), and heated for one hour at 80° C. with 1% caustic soda solution, (200 cc.) in a 250 cc. conical flask the mouth of which was closed with a pear-shaped bulb. It was then washed and well wrung under the hot water tap, similarly heated for one hour with 0·5% hydrochloric acid solution (200 cc.) at 80° C., and again washed until free from acid. It was boiled for half an hour with distilled water, again washed, dried for some hours at 110° C., and weighed. In order to take account of any China clay which the process might have failed to remove, the weighed, de-sized cloth was ashed in pastille form at a bright red heat and the weight of the ash determined. The weight of total size in the cloth was calculated from the loss of weight on desizing corrected for the residual ash (due to unremoved clay) and the desizing blank. The result was expressed as a percentage on the weight of the original oven-dry cloth, and for this purpose a moisture determination was made on a separate one-gram sample of the air-dry material. The method described differs from that given by Thomson not only in the additional operation of ashing, but also in the use of a lower temperature (80° C. instead of 100° C.) and weaker acid (0·5% hydrochloric acid instead of 1 per cent). No serious claim can be made that the latter modifications represent either an improvement on, or a detriment to, the original method; they were adopted simply to preserve continuity with previous work in these laboratories. The ash content of *unsized* cotton after the prescribed treatment with alkali, acid, and water, is usually below 0·1% of its weight, and only a small error is involved in assuming that the weight of ash in the desized cloth is equal to that of the unremoved clay, when allowance is made for the loss of combined water suffered by the clay on ignition.

(2) *Malting Method*—The sample of cloth for analysis, weighing about five grams, was extracted for one hour with chloroform in a Soxhlet apparatus. The chloroform was allowed to dry off completely in the air, and the cloth was well washed and wrung in hot water. It was then allowed to lie overnight in 0·5% "diastafor" solution at 60° C., again thoroughly washed with hot water, and finally dried at 110° C. and weighed. The weighed cloth was ashed in pastille form and the weight of the ash determined. The size content of the cloth, again referred to the original oven-dry material, was calculated from the loss of weight on desizing corrected for residual ash (clay) and desizing blank. The ash content of *unsized* cotton after the malting process—which does not include an acid treatment—is greater than the ash content after the scouring process, and a correction on this account is included in the mean value adopted for the desizing blank (see below).

In both methods of analysis definite procedures were followed in the preparation of samples, and in the various washing processes. These are given in detail under the description of the method finally chosen as a standard (page T472).

Desizing Blanks

Eighteen weft or unsized warp yarns representing many different varieties of cotton were submitted to the scouring and the malting treatments described above. The losses of weight experienced by them—their

Table I—Desizing Blanks

Yarn Sample No. and Quality	Scouring blank %		Malting blank % Over-all blank		Malting blank % Blank due to Ash		Ratio Malting blank / Scouring blank
		Mean		Mean		Mean	
American—							
134, 25's Texas .	3·44, 3·46	3·5	2·71, 2·42	2·6	0·21, 0·21	0·2	0·74
149, 36's ,, ..	4·53, 4·56	4·5	3·34, 3·26	3·3	0·20, 0·25	0·2	0·73
168, 30's ,, ..	4·45, 4·43	4·4	3·31, 3·22	3·3	0·17, 0·18	0·2	0·75
188, 28's ,, ..	4·51, 4·82	4·7	3·22	3·2	0·22	0·2	0·68
222, 36's ,, ..	4·29, 4·22	4·3	3·16, 3·12	3·1	0·19, 0·19	0·2	0·72
212, 20's Memphis	4·60, 4·62	4·6	3·11, 3·11	3·1	0·19, 0·21	0·2	0·68
Egyptian—							
128, 2/50 Sakel ..	5·00, 5·10	5·1	3·29, 3·41	3·4	0·24, 0·22	0·2	0·67
129, 2/50 Uppers ..	4·47, 4·58	4·5	3·00, 3·07	3·0	0·25, 0·29	0·3	0·67
130, 2/50 Sakel ..	5·02, 5·18	5·1	3·44, 3·62	3·5	0·23, 0·26	0·2	0·69
229, 40's ,, ..	5·10, 5·20	5·1	3·36, 3·30	3·3	0·20, 0·23	0·2	0·65
South American—							
152, 2/50 Brazilian	5·18, 5·39	5·3	3·92, 3·70	3·8	0·23, 0·19	0·2	0·72
153, 2/50 Peruvian	4·31, 4·10	4·2	3·28, 2·96	3·1	0·20, 0·18	0·2	0·72
213, 20's Tanguis ..	4·27, 4·56	4·4	3·03, 3·06	3·0	0·20, 0·22	0·2	0·68
Indian, Native—							
141, 16's Broach ..	6·31, 6·37	6·3	4·57, 4·33	4·5	0·22, 0·20	0·2	0·72
202, 20's Surat ..	7·10, 7·22	7·2	5·09	5·1	0·24	0·2	0·71
Indian-American—							
196, 30's Punjab ..	4·58, 4·47	4·5	3·27, 2·93	3·1	0·25, 0·24	0·2	0·69
East African—							
169, 30's	6·13, 6·07	6·1	4·58, 4·41	4·5	0·23, 0·29	0·3	0·74
Miscellaneous—							
100, 20's	3·61, 3·92	3·8	2·77, 2·67	2·7	0·20, 0·21	0·2	0·71
Means		4·9		3·4		0·2	0·70

desizing blanks—are given in Table I, expressed as percentages on the weight of the treated cotton. The final ashing operation was not included in the scouring treatment since the percentages of ash in an unsized grey cotton which has been treated with hot caustic soda, hydrochloric acid, and distilled water is negligible for the purpose of this analysis. With the malting method the ashing operation was included, and the Table shows what proportion of the total blank correction is due to residual ash.

Comparison of the Two Methods of Analysis

Ten cloths containing different amounts of total size varying from 5% to 30% on the weight of the cloth, or roughly 10% to 80% on the weight of the warp, were analysed both by the scouring and the malting methods described, and the results are given in Table II. No unsized warp yarns were available as controls, and the mean values of the desizing blanks for American and Egyptian cottons—4·6% and 3·2%—were used as corrections.

On the average, the malting method yielded a value for the total size content 0·3% higher than that given by the scouring method, the maximum difference being 1·7% in a cloth (No. 42/1) which contained a very high proportion of fats, namely 2·7% on the weight of the cloth. When the amount of fatty material on the cloth was low (samples 36/3 and 45) the scouring method occasionally gave the higher value. In general, the results of duplicate measurements are in better agreement when carried out by the malting than by the scouring method although this is not very well illustrated in the Table. When two duplicate determinations are made side by side by the scouring method the results are usually in good accord, but entirely independent determinations done at different times frequently show much greater discrepancies. This does not apply to the malting method, and independent measurements are usually in reasonable agreement, such differences as are observed being more probably due to variable sizing than faults in the method. Considerable differences undoubtedly occur at times in the size weighting from place to place in the same cloth.

Table II—Comparison of the Two Methods of Analysis

Cloth No	Total Size, %					Clay in Original Cloth %	Clay remaining in desized cloth before ashing, %			
	Scouring method (1)		Malting method (2)		Difference (2)—(1)		Scouring method		Malting method	
		Mean		Mean				Mean		Mean
26/5	24·4, 22·7	23·6	24·1, 24·0	24·1	0·5	11·9	2·6, 2·8	2·7	0·2, 0·2	0·2
36/1	20·3, 21·4	20·9	21·0, 21·9	21·5	0·6	11·0	2·5, 2·7	2·6	0·3, 0·3	0·3
36/2	22·5, 21·8	22·2	23·1, 22·5	22·8	0·6	10·9	2·7, 2·9	2·8	0·2, 0·6	0·4
36/3	29·2, 28·4	28·8	27·9, 28·2	28·1	−0·7	17·3	3·9, 4·0	3·9	0·2, 0·4	0·3
42/1	21·1, 21·2	21·2	22·7, 23·1	22·9	1·7	10·8	3·4, 3·2	3·3	0·7, 0·3	0·5
42/2		11·3	11·0, 12·1	11·6	0·3	2·9		1·1	0·8, 0·6	0·7
42/3	22·8, 24·4	23·7	24·0, 25·0	24·5	0·8	13·2	3·9, 3·6	3·7	0·6, 0·4	0·5
44	16·7, 16·8	16·7	15·8, 16·2	16·0	−0·7	9·2	3·1, 3·0	3·1	1·3, 1·0	1·2
45		12·7		12·3	−0·4	1·0		0·6		0·2
46	5·1, 4·9	5·0		5·4	0·4	—		—		-

The Removal of China Clay

Table II also contains figures for the amount of China clay remaining in the cloths after desizing by the prescribed methods. This is equal to the ash content of the desized materials increased by 12%—the average

loss suffered by dry clays on ignition (Smith[2]). In the case of the malting method, a small correction has been applied for the mean ash content of unsized yarns after submission to the desizing treatment; this correction, obtained from Table I, is 0·2 per cent. The results show that the malting method is much more efficient than the scouring in removing clay, possibly on account of the more complete removal of fatty matter. The determinations of clay in the original cloths were made by the method described by Smith[2].

Removal of Fats in the Scouring Method (without Solvent Extraction)

Three cloths containing considerable amounts of tallow as a size ingredient were desized by the scouring method. The amounts of fat in the original and in the desized cloths were determined by extraction with chloroform, the average value 0·5% being used as a correction for the natural fat and wax content of the unsized cotton. The following results were obtained, and they show that the scouring method may occasionally fail to remove 1% or more of the fatty size ingredients—

Cloth No.	% Fat calculated on the original weight of oven-dry cloth: In original cloth	In de-sized cloth
42/1	2·7	1·2
42/3	3·2	1·2
26/5	2·8	1·0

Standard Method for Total Size Analysis

The results obtained show that the malting process is the more efficient desizing treatment. In a convenient standard method of analysis for routine work it is desirable, however, to reduce the time of the desizing operation to a minimum, and to secure such a complete removal of clay that subsequent ashing is unnecessary. In the following method, which was finally adopted, the material is immersed in the solution of malt extract ("diastafor") for 15 minutes and is submitted to mechanical treatment during the malting. In the previous work the material was allowed to lie in the malting bath overnight, and it is chiefly in this respect, and in the omission of ashing, that the standard method now suggested differs from the experimental procedure first investigated (page T470). It will be shown later that the standard method secures very effective desizing, including the removal of clay. The detailed procedure is as follows—

A square of cloth weighing roughly five grams is cut from the sample, as much care as possible being taken to cut parallel to the warp and weft threads. The sides of the square are trimmed to a complete thread and five of these are then pulled out all round the square so as to leave a fringe, which enables the sample to be handled without the loss of yarn fragments. In the analysis of sized warp, a bundle of threads weighing about five grams is tied loosely round the middle, and particular care is taken to avoid the loss of loose threads during the washing operations. The sample (prepared square or yarn bundle) is weighed in its air-dry condition and a separate sample of about one gram is weighed out for moisture determination.

The material for analysis is extracted for one hour with chloroform in a Soxhlet apparatus, and in routine work a number of samples may be loosely piled together in the extractor. The chloroform is allowed to dry off in the air and the cloth is well washed by alternate immersion in hot, running water and wringing by hand twelve times in succession. It is then alternately immersed in 0·5% diastafor solution (20 to 30 times the weight of cotton) at 50° C., and wrung by hand three times in succession,

finally being returned to the solution, which is then heated to 70° C. The cloth is allowed to remain in the solution for 15 minutes in all; it is then well washed in hot, running water exactly as before, dried at 110° C. side by side with the sample taken for the moisture determination, and both are weighed. It is of importance in this short desizing process to secure good penetration of the diastafor solution into the material, and this is achieved by hand wringing, which also assists the removal of clay.

The size content of the material is calculated from its loss of weight on desizing, its moisture content, and the desizing blank, for which the mean value 3% is adopted in the absence of unsized controls. In order to show clearly the basis upon which the blank corrections are made the actual laboratory record form of weighings and calculations in an analysis by the standard method is given below—

		Weights
(1)	Weighing bottle	(1)
(2)	Do. plus air-dry cloth (prepared square) ...	(2)
(3)	Air-dry cloth	(2) – (1)
(4)	Moisture contained in weight (3) of cloth (calculated from separate moisture determination) ...	(4)
(5)	Oven-dry cloth	(3) – (4)
(6)	Weighing bottle plus oven-dry desized cloth ...	(6)
(7)	Oven-dry desized cloth	(6) – (1)
(8)	Total size (uncorrected)	(5) – (7)
(9)	Blank correction	3% of (7)
(10)	Corrected total size	(8) – (9)
(11)	% Total size on oven-dry cloth	(10) × 100/ (5)

Notes

(1) The rational method of expressing the size content is on the basis of oven-dry material, since the weights of air-dry cotton and size depend on the fortuitous humidity conditions of the atmosphere when the sample is weighed. In this paper the oven-dry weight of the cloth in its loom state, that is, cotton and size, has been used as the basis for calculating results. It is of course also permissible, and in some cases convenient, to calculate size contents on the basis of oven-dry *cotton* in the cloth, that is, desized cloth plus the blank correction, or (7) plus (9) in the above form instead of (5).

(2) It is actually more convenient to dry the sample for analysis in the oven before weighing and analysing it since this yields directly the value of item (5) in the above form, avoiding the necessity for a separate moisture determination and the attendant calculation (4). This procedure is not permissible in the scouring method of analysis when the cloth contains zinc or magnesium chloride, since heating in the presence of these salts causes degradation of the cellulose and therefore results in abnormal losses of weight when the material is subsequently treated with hot alkali. In the malting method, however, which does not include a hot alkaline treatment, no serious error is caused by drying the sample before weighing and analysing it.

(3) When cloth containing large quantities of zinc chloride is submitted to the action of the malt extract, the removal of starch may be incomplete owing to the effect of this salt in depressing the activity of malt enzymes. This source of error is avoided by the thorough washing of the cloth between solvent extraction and malting. Traces of residual chloroform do not affect the efficient removal of starch by malt.

(4) The use of chloroform as a solvent avoids all fire risk. The same supply of chloroform can be used for many analyses without the separation of the fat which has accumulated from previous extraction.

(5) If unsized yarns are available as controls, the true value of the desizing blank can be determined by submitting them to the prescribed desizing treatment. The required value is then given by item (8) expressed as a percentage of item (7), and should replace the average blank of 3% used for the correction in item (9). It will generally be sufficiently accurate to adopt the mean value obtained for the unsized warp and the weft yarns. The mean value recommended for general use when no controls are available (3%) is that obtained from the examination of American and Egyptian cottons (Table I) but, in view of the absence of an ashing operation, it does not include the small ash correction (0·2 per cent).

The standard method described above has been tested on the range of cloths previously used in this work, and Table III contains a comparison of results obtained (1) by the standard method, (2) by the longer malting treatment first investigated, which included ashing, and (3) by the scouring method; the last two are taken from Table II. Table III also contains determinations of residual clay in the samples submitted to the standard method, and shows that the omission of an ashing operation is justified. The difference between the results obtained by the standard method and the longer malting process is negligible with two exceptions, and in view of the probable variations of size content existing in one and the same cloth, the standard method gives as accurate results as are likely to be attained without special sampling over long lengths of cloth.

Table III—Comparison of the Standard, with other Methods of Analysis

Cloth No.	Total size, %			Difference (2) — (1)	Clay remaining in cloth desized by standard method, %
	Standard malting method (1)	Long malting method (2)	Scouring method		
26/5	23·3	24·1	23·6	0·8	0·1
36/1	21·3	21·5	20·9	0·2	0·1
36/2	21·7	22·8	22·2	1·1	0·1
36/3	28·1	28·1	28·8	0·0	0·1
42/1	22·7	22·9	21·2	0·2	0·1
42/2	11·6	11·6	11·3	0·0	0·1
42/3	24·2	24·5	23·7	0·3	0·2
44	16·1	16·0	16·7	−0·1	0·4
45	—	12·3	12·7	—	—
46	5·8	5·4	5·0	−0·4	—

The Determination of Filling in Finished Material

The method described above for determining the proportion of size in grey or loom-state material can also be used for determining the proportion of filling in finished (bleached, dyed, printed, etc.) cotton. Since, however, the natural soluble constituents of cotton are removed more or less completely by any wet process, no correction corresponding to the desizing blank should be applied. In the absence of a control sample, it is impossible to prescribe a general correction, which must in any case be small, and must be neglected altogether in essentially proximate analysis.

As with size analyses, the procedure can often be simplified when something is known of the qualitative nature of the filling.

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35—THE DETERMINATION OF STARCH IN SIZED AND FINISHED COTTON GOODS

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INTRODUCTION AND SUMMARY

The determination of starch in yarn or cloth is essential for any control or experimental work on sizing, desizing, or finishing, and for cloth analysis, particularly when it is desired to ascertain the ratio of antiseptic to starch. Despite its importance, however, the method of determination adopted is almost invariably indirect, the figure returned as starch being the total size or filling less the other ingredients which are found by analysis to be present, so that any error in the analysis is reproduced in the starch content.

Experiments were therefore initiated to find a more reliable and expeditious procedure. The most promising line of attack seemed to lie in converting the starch into glucose by a suitable mixture of diastases, and so obviating interference by other carbohydrates (gums, mucilages, etc.). Takadiastase[3] and a mixture of pancreatic and malt amylases[8] have been claimed to do this. With the former, complete conversion was never attained, but with the related commercial preparation,* Polyzime P, maize, wheat, rice, potato, and other starches were hydrolysed completely to glucose. When the reaction was applied to sized yarns and grey cloths, however, only about nine-tenths of the starch was realised as glucose, and as it had been found that the method would in any case be inapplicable when zinc chloride was present, it was abandoned in favour of the alternative procedure of hydrolysis with acids. Hydrolysis with enzymes may be of definite value, however, when the identity of the carbohydrates in a grey or finished cloth is in question.

The alternative method is based on an earlier observation[5] that the higher the temperature the more rapid is the hydrolysis of starch by dilute mineral acids relative to that of cotton. It is possible, therefore, to convert starch completely to glucose before hydrolysis of the cotton on which it is deposited has gone beyond the very early stages, and, when the conditions are strictly controlled, to obtain a fairly exact and reproducible estimate of the amount of starch present. The actual procedure is to heat the sample for 2½ hours with $N/1$ sulphuric acid in an actively boiling water bath and to determine the glucose formed by the method of Hinton and Macara[7]. An alternative and more specific reaction—conversion of the glucose into carbon dioxide by fermentation with yeast[6]—failed to give anything approaching quantitative results, although a variety of conditions were tried.

The method is therefore similar in general outline to one described by Derrett-Smith[4] quite recently for use with linen goods, but it differs in several important details. Derrett-Smith varies the size of the sample used for analysis according to the quantity of starch it contains, and since for the range of starch contents commonly found in cotton goods the size of the sample will be from 0·05 to 0·25 gram, variability of the material must lead to very considerable errors. To avoid this it is desirable whenever possible to hydrolyse larger quantities of carefully sampled material and to

* Several widely advertised proprietary preparations both for desizing (such as Polyzime P) and for sizing or finishing (such as Blandola, Gum Gatto, Gum Tragon, and Muciline) are mentioned in this memoir. The authors do not express any opinion as to the advantages or disadvantages arising from their use.

determine glucose in an aliquot part of the resulting solution. The two methods also differ in the procedure selected for determination of the glucose. Derrett-Smith employs the Schwalbe-Braidy solutions used in these laboratories to determine the "copper number" of cottons[1] or of starches[5]. For routine analysis, however, the iodometric procedure is preferred on account of its greater simplicity, speed, and range. As both methods are referred to frequently throughout the paper, it will be convenient to distinguish them briefly as the "copper" and "iodine" methods respectively.

A correction must be applied for substances present in the cotton, or formed from it by the action of the acid, which react with the iodine or copper solutions, and the value of the method will depend on (*a*) the reproducibility of such "blank" determinations, (*b*) the variability of the correction for different cottons, and (*c*) the behaviour of carbohydrates other than starch and its derivatives. This last is generally unimportant in the analysis of sized goods, where gums, marine sizes, etc., are rarely used in more than minute quantities, but may sometimes be important in the analysis of finished cloths.

A series of determinations by the iodine method on one unsized cotton over a period of several months gave a maximum deviation from the mean corresponding to 0·2% of starch. This is probably due to inevitable slight variations in the temperature of the bath and would not arise when the blank determination is being made on the corresponding unsized material or when a standard blank is included in each series of analyses (see page T480).

For a series of 28 unbleached cottons of different origin the blank varied less than in either of the indirect methods of analysis described in the preceding Memoir[2] (Table II), and with cottons other than Indian the maximum error introduced into either the "iodine" or "copper" determination by the use of a mean correction value is 0·4 per cent. With native Indian cottons the error introduced by the assumption of a mean blank is liable to be greater. It is about the same in the "iodine" determination as in the "malting" method of determining total size[2], and rather smaller in the "copper" determination, but in all three it is less than in the "scouring" method of determining total size[2]. When it is known that the cotton is Indian, a more suitable blank correction may of course be employed.

Blank determinations have also been made on a number of cottons scoured with 1% caustic soda at 20 lb. excess pressure. Excluding native Indian cottons the maximum variation from the mean proved to be 0·3% in the "iodine" method and 0·15% in the "copper" method. The native Indian cottons showed rather greater divergences. The values for samples scoured with 1% caustic soda at 100° C. or with 3% caustic soda at 40 lb. excess pressure differed only slightly from those obtained with the same cottons after scouring at 20 lb. excess pressure. The variation from cotton to cotton becomes smaller, however, the more severe the scouring treatment.

In the indirect methods of analysis, glycerin, gums, marine sizes, gelatin, gluten, and the non-volatile products formed from starch or gluten during the fermentation of wheat flour are generally returned as starch. Several substances occasionally used in sizing or finishing have been submitted to the procedures adopted in the present experiments (Table VI) because the simple methods employed for the determination of glucose are not specific and embrace some of the products formed from them by the action of acids. Glycerin does not interfere with either method and the "starch equivalents"

of gelatin and gluten are negligible in the "copper" method and relatively low in the "iodine" determination. The gums (tragacanth, tragon, gatto and muciline) react in both as if they contained an amount of starch at least equal to that present in wheat flour, whilst the seaweed products (Irish moss and Blandola) give intermediate values. The starch content of wheat flour differs only slightly from the theoretical value on account of the low starch equivalent of the gluten. Obviously, therefore, the method is liable to error if carbohydrates other than starch are present.

The use of the method in cloth analysis is illustrated by Tables VII and VIII. The first of these contains comparative measurements by the direct method and the "scouring" procedure on a series of plain sized warps of which the unsized yarn was available. The results agree so closely that it is difficult to understand Derrett-Smith's[4] failure to obtain values in agreement with the "copper" method by desizing bleached and starched linen fabrics with enzymes. In the second are given direct and indirect determinations of starch (or flour), in a series of cloths containing starch or wheat flour (fermented or steeped) admixed with fat, magnesium chloride, zinc chloride or other antiseptic, and China clay. The results are again in substantial agreement.

It may be concluded, therefore, that the direct method affords a more rapid and, on the whole, more accurate determination of starch than any hitherto available for use with cotton goods.

EXPERIMENTAL

1 – Comparison of the "Iodine" and "Copper" Methods for Determining Glucose

Table I

Weight of glucose (gram)	$N/20$ Iodine, c.c. used		$N/25$ permanganate, c.c. used	
	Total	Calc. for 0·01 gram	Total	Calc. for 0·01 gram
0·0025	0·54	2·16	1·47	5·88
0·0050	1·09	2·18	4·87	9·74
0·0075		—	8·13	10·84
0·0100	2·22	2·22	11·54	11·54
0·0125	-	-	14·42	11·54
0·0150	3·31	2·21	17·61	11·74
0·0175	-		20·42	11·67
0·0200	4·43	2·22	23·11	11·55
0·0225		-	25·78	11·46
0·0250	–		28·89	11·56
0·0275	—		31·05	11·29
0·0300	6·71	2·24	33·33	11·11
0·0325	—	—	34·92	10·74
0·0350	--		36·67	10·48
0·0375	—		39·49	10·53
0·0400	9·03	2·26	--	—
0·0500	11·06	2·21	—	--
0·0600	13·33	2·22	—	-
0·0700	15·40	2·20	-	—
0·0800	16·51	2·06	-	--
0·0900	16·78	1·86		
0·1000	17·36	1·74		

The experimental procedures described in the following section were used, a solution of glucose (50 c.c.) replacing the hydrolysate from the sample under test. The results (Table I) clearly demonstrate the greater range

of the "iodine" method, which may be used for any quantity of glucose that uses up less than three-fifths of the iodine added in the determination, that is, any quantity up to 0·07 gram. The range of the "copper" method is much smaller, for the titration with $N/25$ potassium permanganate should not be less than 10 c.c. or more than 30 c.c., equivalent to 0·01 gram and 0·025 gram of glucose. Within this range, which is rather smaller than is suggested by Derrett-Smith[4], the weight of reduced copper corresponds to a consumption of 4 atoms of oxygen to each molecule of glucose. The oxidation proceeds therefore, considerably further than in the "iodine" method, where one atom of oxygen is used to each molecule of glucose. The lower limit is not important, for titrations of less than 10 c.c. are but rarely encountered; the upper limit is important, however, and is fixed not only by the fall in the titre but also by a loss of concordancy in duplicate tests. In determining the "copper number" of cottons[1] or of modified starches[5], the weight of reduced copper becomes very nearly constant only after heating for 3 hours. With glucose, however, the reaction is completed more rapidly, and Derrett-Smith's observation that nearly constant values are reached after heating for half an hour is confirmed; the following figures were obtained, for example, with solutions containing 0·0175 gram. of glucose—

Time of Heating	*N*/25 permanganate, c.c. used	
	Total	Calculated for 0·01 gram
30 minutes	19·68	11·24
60 minutes	19·68	11·42
120 minutes	20·20	11·56

2 Procedure for the Determination of Starch in Yarns or Fabrics

A sample weighing about 10 grams is cut into small pieces (⅜ in. × ⅜ in.), thoroughly mixed, and the moisture content determined on a 1 gram portion. At the same time, 2·5 gram is weighed out, placed in a 100 c.c. conical flask, and wetted out by heating just to boiling with 60 c.c. of water; the neck of the flask is closed with a combined glass pear bulb and stirring rod. After cooling, 20 c.c. of $4N$ sulphuric acid is added and the flask is placed in a rapidly boiling water bath for 2½ hours, the contents being stirred vigorously for the first three minutes in order to promote the escape of air and to bring them rapidly and uniformly to the temperature of the bath. The flask is cooled again, the mixture filtered through a 2 in. Buchner funnel, and the cotton washed repeatedly with water (100 c.c. in all); 19 c.c. of $4N$ sodium hydroxide is added slowly from a burette or pipette to the filtrate, with vigorous agitation to prevent the solution from becoming alkaline locally, and the whole is made up to 250 c.c. Glucose is estimated in this solution as follows—

Iodine method—Twenty-five c.c. of the solution is titrated with $N/2$ sodium hydroxide. The glucose is then determined in a 50 c.c. portion by adding 25 c.c. of $N/20$ iodine solution followed by the volume of $N/2$ sodium hydroxide required to neutralise (as determined on the 25 c.c. portion) plus 3·12 c.c. The sodium hydroxide must be added slowly with constant shaking. In this way the exact ratio of sodium hydroxide to iodine specified by Hinton and Macara[7] is maintained. After standing for 10 minutes

at 20° C., the solution is acidified by adding 1·6 c.c. of $4N$ sulphuric acid, and the excess of iodine is titrated with $N/20$ sodium thiosulphate. It is convenient to carry out the estimation in a 250 c.c. glass stoppered bottle. If more than three-fifths of the iodine is used up by the glucose, the titration must be repeated using a 25 c.c. portion of the solution, whilst if the volume of the iodine solution used up is very small, a more accurate result is obtained by repeating the titration with a 100 c.c. portion. It should, however, be unnecessary to vary the volume unless the starch content of the sample is greater than 10 per cent. The reducing substances produced from the cotton itself may be allowed for by the use of the mean blank correction as determined on page T480. Alternatively a sample of the unsized yarn or other suitable blank may be treated as described above. Where the size is not essentially starch the approximate size content must be determined.

The result is calculated as follows—If T c.c. of $N/20$ iodine are used up by 1 gram of the sized sample containing x per cent of moisture, then 1 gram of the dry sample will require—

$$\frac{100T}{100-x} \text{ c.c.} = T'$$

Similarly if t c.c. of $N/20$ iodine are required by 1 gram of the blank containing y per cent of moisture, then 1 gram of the dry blank will require—

$\frac{100t}{100-y}$ c.c. $= t' =$ 8·15 c.c. if the mean correction value for grey cotton is used or 4·31 c.c., using the corresponding value for scoured cotton.

Then S, the starch content per cent., is given by—

$$S = 0{\cdot}417 \left[T' - t'\frac{(100-c)}{100}\right]$$

where c is the total size per cent. and 1 c.c. of $N/20$ iodine is equivalent to 0·00405 gram of pure starch or to 0·00417 gram of an average commercial starch.

Copper method—As the final titration with $N/25$ potassium permanganate should not be less than 10 c.c. or more than 30 c.c the quantity of the solution used for analysis depends on the starch content of the sample of yarn or cloth If it contains less than 2½% of starch a volume of 50 c.c. is used; if it contains from 2½ to 8% of starch the volume is reduced to 25 c.c., and if it contains more than 8% the quantity is still smaller. ***If the volume of the hydrolysate used is less than 50 c.c. it should be made up to that volume before proceeding with the analysis*** (*Solution C*). The following procedure is recommended—

Solution A—Pure copper sulphate ($CuSO_4$ $5H_2O$) 100 grams; water to 1 litre.

Solution B—Anhydrous sodium carbonate, 130 grams; sodium bicarbonate 50 grams; water to 1 litre.

Solution C is placed in a conical flask of about 120 cc. total capacity and brought to the boil. Nine grams of a mixture of sodium bicarbonate (50 parts), and sodium carbonate (130 parts) are added to 45 c.c. of solution B, and 5 c.c. of solution A introduced by means of a pipette. The mixture is raised to the boil, poured rapidly into solution C and thoroughly mixed with it by means of a combined glass pear bulb and stirring rod. The flask is then immersed to the neck in an actively boiling water bath and heated for 1 hour. The precipitated cuprous oxide is collected in a sintered glass

funnel containing a pad of finely shredded asbestos, as described by Derrett-Smith, or in a small Buchner funnel containing a double layer of Whatman filter paper No 44, covered with purified finely shredded asbestos. The analysis is then completed as described by Clibbens and Geake.[1] The result is calculated as follows—If T c.c. of $N/25$ permanganate are used up by 1 gram of the sized or filled sample containing x per cent of moisture, then 1 gram of the dry sample will require—

$$\frac{100T}{100-x}\text{ c.c.}=T'$$

Similarly if t cc. of $N/25$ permanganate are required by 1 gram of the blank containing y per cent of moisture, then 1 gram of the dry blank will require—

$$\frac{100t}{100-y}\text{ c.c.} = t' = 30{\cdot}5 \text{ c.c.}$$ if the mean correction for grey yarns is used or 20·1 cc. if the mean correction for scoured yarns is used.

Then S, the starch content per cent., is given by—

$$S = 0{\cdot}082\left[T' - t'\frac{(100-c)}{100}\right]$$

where c is the total size or filling per cent and 1 c.c. $N/25$ permanganate is equivalent to 0·00078 gram pure starch or 0·00082 gram of an average commercial starch.

3—Reproducibility of Blank

Duplicate determinations by the "iodine" method on one cotton made in the same bath gave values which were almost identical, but over a period of several months, using several baths, the values varied slightly. The extent of this variation is indicated by the following values for the starch equivalent of Texan yarn 222, thoroughly washed with water, obtained at intervals over a period of three months.

Starch Equivalent (per cent.)

2·30	2·44	2·47	2·48	2·58	Mean value, 2·46 per cent.
2·34	2·40	2·33	2·40	2·56	Maximum variation from mean
2·50	2·46	2·40	2·68	2·58	value, 0·2 per cent.

The slight differences are probably due to inevitable slight variations in the temperature of the bath, and can be avoided by including a standard blank in each series of samples to be tested.

4—The Starch Equivalents of Different Cottons

Grey yarns—Where the unsized cotton is not available, a mean blank figure obtained from several varieties must be used. This has been obtained by measurements on a series of 15 cottons of different origin, which had already been employed for the same purpose in the determination of total size by the "malting" and "scouring" methods (Table II). From these figures and a number obtained with other cottons which are included in the table, it is evident that the maximum error introduced by the absence of unsized material for comparison is 0·4 per cent, save in the case of native Indian cottons which give higher blanks in all three methods of analysis than American and Egyptian cottons. If it is known that the sample has been manufactured from Indian cotton a more suitable correction value may be used. The error introduced by the absence of an unsized sample is rather smaller on the whole than in the treatment with malt, which has been selected[1] as the most suitable for indirect analysis.

Table II

A Comparison of the Blanks in Different Methods of Size Analysis

Cotton	Blank corresponds to starch (%) on dry sample: Direct, Iodine	Direct, Copper	Malting	Scouring
188 Texas	3·2	–	3·2	4·7
134 Texas	3·6	–	2·6	3·5
149 Texas	3·1	2·1	3·3	4·5
222 Texas	3·0	2·1	3·1	4·3
168 Texas	3·1	2·4	3·3	4·4
212 Memphis	3·0	2·3	3·1	4·6
213 Tanguis	3·4	2·7	3·0	4·4
196 Punjab-American	3·1	2·5	3·1	4·5
169 East African	3·6	2·8	4·5	6·1
130 Sakel	3·7	2·9	3·5	5·1
219 Sakel	3·8	2·9	3·3	5·1
128 Uppers	3·6	2·4	3·4	5·1
129 Uppers	3·4	2·6	3·0	4·5
202 Surat	4·9	3·5	5·1	7·2
141 Broach	4·6	3·2	4·5	6·3
Mean	3·5	2·6	3·5	5·0
Range	3·0—4·9	2·1—3·5	2·6—5·1	3·5—7·2
Mean of all the above cottons other than native Indian	3·4	2·5	3·2	4·7
Range	3·0—3·8	2·1—2·9	2·6—4·5	3·5—6·1
255 Sakel	3·8	2·7		
159 Sea Island	3·4			
- Pernam	3·5			
64 Ceara	3·2			
— Smooth Peruvian	3·8			
— Australian	3·2			
148 Sakel	3·6			
158 Uppers	3·3			
49 Mitafifi	3·2			
73 Brown Mitafifi ..	3·7			
13 Broach	5·1			
3 Oomra	3·8			
9 Bengal	4·2			
1 Surtee	5·0			

Desizing—Where technically desized samples are being examined, the blank can be prepared from the fent itself either by (*a*) steeping overnight at 40° C in a 0·5% solution of Takadiastase, followed by thorough washing, or (*b*) steeping overnight in a 0·5% solution of malt extract at 55° C, washing, rinsing in $N/50$ acetic acid to remove products absorbed from the malt, and finally washing in water.

Scoured yarns—Determinations on a series of yarns scoured at 20 lb. excess pressure with 1% caustic soda are given in Table III. For cottons other than native Indian, the maximum error introduced by the assumption of a mean blank is 0·3% for the "iodine" method and 0·15% for the "copper" method. The effect of variation in the scouring process is illustrated by Table IV, which shows that the differences between samples scoured with 1% caustic soda at 100° C., with 1% caustic soda at 20 lb. excess pressure, and with 3% caustic soda at 40 lb. excess pressure are relatively small, and indicates that as the severity of scouring is increased, the variation from cotton to cotton diminishes.

Table III

Starch Equivalents of Scoured* Yarns

Sample	Starch equivalent (%)	
	Iodine method	Copper method
222 Texas	1·8	1·6
149 Texas	1·6	1·5
168 Texas	1·5	1·6
212 Memphis	1·6	1·5
213 Tanguis	1·9	1·7
196 Punjab American	1·6	1·6
169 East African	1·7	1·6
255 Sakel	2·1	1·8
130 Sakel	1·9	1·7
219 Sakel	1·9	1·7
128 Uppers	1·8	1·8
129 Uppers	1·7	1·7
141 Broach	2·4	2·0
Mean	1·8	1·7
Range	1·5–2·4	1·5–2·0
Mean for all samples other than native Indian	1·8	1·65
Range	1·5–2·1	1·5—1·8

* Scoured at 20 lb excess pressure with 1% caustic soda

Table IV

Starch Equivalents of Scoured Yarns. Effect of Variation in Scouring Process

Sample	Starch equivalent (%)	
	Iodine method	Copper method
222 *Texas*		
Washed with water	2·6	1·95
Scoured with 1% NaOH at 100° C.	1·8	1·5
Scoured with 1% NaOH at 20 lb. excess pressure	1·8	1·6
Scoured with 3% NaOH at 40 lb excess pressure	1·7	1·6
255 *Sakel*—		
Washed with water	3·2	2·4
Scoured with 1% NaOH at 100° C.	2·2	1·8
Scoured with 1% NaOH at 20 lb excess pressure	2·1	1·8
Scoured with 3% NaOH at 40 lb. excess pressure	1·9	1·7
141 *Broach*		
Washed with water	3·7	2·9
Scoured with 1% NaOH at 100° C.	2·5	2·2
Scoured with 1% NaOH at 20 lb. excess pressure	2·4	2·0
Scoured with 3% NaOH at 40 lb excess pressure	2·0	1·8

5—The Starch Equivalents of Commercial Starches and Flours

In Table V are given the apparent starch contents of a number of commercial starches and flours obtained from industrial sources, as determined by the "iodine" and "copper" methods after the standard hydrolysis procedure already described. These have been used to determine the mean equivalents for commercial starches given on pages T479 and T480.

Table V

Starch Equivalents of Commercial Starches and Flours

Sample	Starch equivalent (%)	
	Iodine method	Copper method
Maize starch (2 samples)	*97·4*, 95·9	*94·7*
Farina (7 samples)	*97·9*, 98·1, 99·0, 98·3 97·6, 97·7, 98·1	*96·6*
Tapioca starch	*96·5*	*95·7*
Sago starch	*97·3*	*93·0*
Wheat starch (2 samples)	*96·8*, 96·6	*92·2*
Rice starch	*96·1*	*95·5*
Wheat flour (3 samples)	*87·4*, 87·6, 86·9	*78·4*

Values in italics were obtained on the same sample by the two methods

6—Starch Equivalents of Other Substances that may be Present in Size Mixings or Finishing Pastes

The substances given in Table VI have been submitted to the standard hydrolysis procedure and their apparent starch equivalents determined. Glycerin does not interfere with either method. Gelatin and gluten do not interfere with the "copper" method but give low values in the "iodine" method. Any gums present are, however, estimated substantially as starch, whilst Irish moss and Blandola interfere to a less extent.

Table VI

Starch Equivalents of Other Substances which may be Present in Size Mixings

Substance	Starch equivalent (%) of *dry* substance	
	Iodine method	Copper method
Gum tragacanth	85	54
Gum tragon (Tragasol)	83	87
Gum gatto, super	86	91
Muciline	83	85
Irish moss	50	35
Blandola	53	34
Gelatin	27, 17	nil
Glycerin	3	nil

7 A Comparison of Direct and Indirect Starch Determination

The determinations given in Table VII afford a very satisfactory check on the validity of the direct starch determination in presence of cotton, for the samples were pure sized without the addition of fat, and unsized yarns were also available. The indirect determinations were made by the "scouring" method, and the values obtained by the two methods are in very good agreement.

In the second series (Table VIII), unsized reference samples were not available, so the "malting" method was used to determine total size. The starch (or flour) contents were obtained indirectly by determining the other constituents of the size mixings, and subtracting these from the total size. Starch was determined directly by the procedure already outlined, and,

Table VII

Direct and Indirect Starch Estimations on Warps Sized Pure without Fat

Sample	Starch content (per cent) Direct	Mean	Indirect	Mean
Sago 1A	15·8, 16·0	15·9	15·9, 16·1	16·0
Sago 1	16·5, 16·5	16·5	16·5, 16·5	16·5
Sago 2	10·8, 10·5	10·7	10·3, 10·8	10·6
Maize 1	12·6, 12·5	12·6	12·6, 12·2	12·4
Maize 2	8·0, 7·8	7·9	7·6, 7·7	7·7
50	9·6, 10·0	9·8	10·1, 10·2	10·2
52	8·9, 9·2	9·1	9·4, 9·3	9·4
49	10·7, 10·8	10·8	11·1, 11·1	11·1
51	9·6, 9·2	9·4	9·5, 9·5	9·5
57	21·2, 21·2	21·2	21·9, 22·2	22·1
58	18·8, 19·2	19·0	19·8, 19·8	19·8
60	17·9, 18·2	18·1	18·0, 18·2	18·1

Table VIII

Direct and Indirect Starch Determinations on Samples Containing Chlorides, Antiseptics, and Clay, in Addition to Starch or Flour

Sample	Mixing contains	Total size (%)	Total constituents other than starch or flour (%)	Starch or flour (by difference (%)	Starch (%) (direct)	Flour calculated from direct starch (%)
26/5	flour	24·1	16·8	7·3	6·5	7·3
36/1	,,	21·6	13·7	7·9	6·1	6·9
36/2	,,	22·8	13·4	9·4	7·3	8·2
36/3	,,	28·1	20·0	8·1	7·6	8·5
42/1	,,	22·8	15·2	7·6	5·6	6·3
42/3	,,	24·4	17·8	6·6	6·0	6·7
55/1	,,	14·8	2·6	12·2	10·9	12·3
55/2	,,	15·4	3·9	11·5	10·8	12·2
55/3	,,	10·8	1·4	9·4	8·3	9·3
48	,,	25·8	17·9	7·9	5·8	6·5
45	170 parts flour to 110 parts sago	12·3	1·5	10·8	10·4	11·2
42/2	sago	11·5	5·8	5·7	5·7	-
46	sago and farina	5·4	1·5	3·9	4·0	-
40	starch	3·1	0·3	2·8	2·7	—

Table IX

Variation in Size Content over a Warp

Warp	Variation in starch content of random samples (%)	Variation in starch content, sampled material (%)
57	20·4 to 21·4	20·9 to 21·4
58	18·8 to 22·0	18·8 to 19·2
59	18·7 to 22·6	18·7 to 18·9
60	17·6 to 19·3	17·8 to 18·2
49	9·7 to 10·8	10·7 to 10·8
50	8·9 to 10·0	9·6 to 10·0
51	8·6 to 9·6	9·2 to 9·6
52	7·8 to 9·4	8·9 to 9·2

when necessary, the corresponding figure for flour has been calculated from the data given in Table V. In most cases the agreement is good, and the figures differ significantly only in a few of the flour mixings where the direct value is occasionally lower than the indirect. This is not unexpected in view of the changes which may occur during the fermentation or steeping of the flour.

8.—Sampling

The necessity for sampling yarn or cloth before analysis is shown plainly by the figures given in Table IX. The determinations were made (*a*) on samples taken at random along a bunch of sized warp ends, and (*b*) on samples from a quantity of 10 grams cut up into short lengths as described on page T478 and thoroughly mixed. It is therefore recommended that this procedure should be adopted wherever possible.

9.—Conversion of Starch into Glucose by Enzymes

Following several claims in the literature that starch may be hydrolysed quantitatively to glucose by Takadiastase, a concentrated preparation of this enzyme was tested under the following conditions and with the results noted.

To 0·15 gram of dry farina, gelatinised in 50 c.c. of water, were added 5 c.c. of a 1% solution of sodium chloride, 5 c.c. of a 2*M* sodium acetate buffer solution (*p*H5), various quantities of a 2% solution of Takadiastase in 0·5% sodium chloride solution, and 0·25 c.c. of toluene. The mixture was incubated at 40° C. for 18 hours, and the glucose formed estimated by the "iodine" method, a corresponding blank experiment being carried out without the starch. The following results were obtained—

Ratio, starch to Takadiastase	Proportion of starch converted to glucose
$1\frac{1}{2}$ to 1	92 per cent
3 to 1	89 ,,
6 to 1	82 ,,
12 to 1	70 ,,

By determination of the glucose formed on acid hydrolysis the farina contained 98·3% of starch. Takadiastase failed therefore to achieve complete conversion, but experiments with the related commercial preparation, Polyzime P, were more successful. In these, the ratio of starch to Polyzime P was maintained at 1·5 to 1, and the incubation at 40° C. was continued for periods of one-half to 18 hours with the following results—

Time of incubation (hrs.)	Proportion of starch converted into glucose
$\frac{1}{2}$	87 per cent
1	90 ,,
2	96 ,,
4	100 ,,
18	100 ,,

In further experiments a period of incubation of 18 hours was employed, and the *p*H of the medium was varied. The conversion proved to be relatively insensitive to such changes in the range *p*H 3·6—7.

*p*H of medium	Proportion of starch converted into glucose	*p*H of medium	Proportion of starch converted into glucose
3·6	99 per cent.	6·0	98 per cent.
4·0	98 ,,	6·5	96 ,,
4·6	100 ,,	7·0	90 ,,
5·0	100 ,,	7·5	64 ,,
5·6	99 ,,		

The reaction was next applied to a number of starches, as it was possible that the conversion to glucose might not be complete in the case of the starches which contain hemicellulose. As shown below, however, the conversion was complete with all the starches examined.

Sample	Starch content (%) calculated from glucose produced by	
	Acid hydrolysis	Polyzime P
Commercial sago	97·3	96·5
,, tapioca	96·5	96·0
,, wheat	96·8	96·9
,, maize	97·4	97·0
,, rice	96·1	96·0

This particular sample of Polyzime P was therefore suitable for investigating the possibility of the enzymic conversion to glucose of the starch in sized yarns or fabrics. Experiments were therefore made on the series of warps sized with maize starch, which were used to compare direct measurements of starch by acid hydrolysis with indirect determinations by the "scouring" method. (see Table VII.) The tests were made on well-sampled material in the following manner, the results being checked by concurrent determinations by the method described on page T478.

The sized warp (2·5 gram) was boiled with 150 c.c. of water to wet out the cotton thoroughly. The mixture was cooled, and 15 c.c. of a 1% solution of sodium chloride, 15 c.c. of a 2*M* sodium acetate buffer solution (*p*H5), 15 c.c. of a 2% solution of Polyzime P in 0·5% sodium chloride and 1 c.c. of toluene were added and the whole was incubated for 18 hours at 40° C., a corresponding blank experiment being conducted on the unsized yarn. The results are given in the following Table—

Warp	Starch content (%)		Ratio B to A
	By Acid (A)	By Polyzime P (B)	
49	10·8	9·6	0·89
50	9·8	9·3	0·95
51	9·4	8·6	0·91
52	9·2	8·3	0·90
57	21·3	19·5	0·92
58	18·9	17·7	0·94
59	18·9	17·0	0·90
60	18·2	17·1	0·94

Very similar results were obtained with a number of cloth samples, so the conversion to glucose of the starch present on a sized warp or cloth is

not complete by this treatment. The treated yarns and cloths still gave a faint blue coloration with iodine, but although numerous variations of the procedure described above were made, no more complete conversion was attained.

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Shirley Institute
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36—OBSERVATIONS ON THE APPARENT FINENESS AND FREEDOM FROM KEMP OF NATURALLY-COLOURED WOOLS

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The statement is often made that the wool of coloured sheep is finer than the wool of the ordinary white sheep of the stock from which they are derived. It has also been stated that the fleeces of coloured sheep appear to be free from kemp, or much freer from kemp, than corresponding white sheep of a mountain type.

A superficial examination appeared at first sight to confirm these beliefs. Ordinary white Welsh Mountain sheep usually show a considerable proportion of kemp. In the Black Welsh Mountain breed, which has been developed by selection from the ordinary Welsh breed, the fleeces appeared to be free from kemp fibres. It is true that mixed up with the wool were to be seen many short, coarser fibres, but these did not seem to be unduly coarse, and looked as though they had little in common with the coarse white kemp fibres of the white sheep. A white sheep was examined that had segregated out in a Black Welsh flock. Its fleece was particularly kempy and the contrast with the black fleeces of the rest of the flock was striking.

In connection with experiments that are being conducted at the University College of North Wales, Bangor, on coat colours and patterns in the sheep, several types were used whose coats showed a pattern of black and white. An examination of the fleeces of these sheep seemed to reveal a remarkable change in structural characteristics in passing from a white to a black area. In the case of badger-face and reversed badger-face sheep* the line of division between black and white areas is usually sharp and distinct, particularly the division between the sides of the body and the ventral surface. These two patterns show a reversal of colour. In the badger-face sheep the body generally is white and the ventral surface black, whilst in the reversed badger-face sheep the body is black and the ventral surface white, the line of division in both cases being similarly situated. In the case of sheep showing these patterns, many individuals were examined, the white areas of whose fleeces contained very large amounts of kemp, and it seemed to be the case that the closely adjacent black areas were both finer and far more free from kemp, or rather that the coarse fibres that occurred in the coloured areas seemed to be very much finer than the white kemp. This was equally true whether the white area was ventral or not.

It was decided to make a number of observations in order to determine the basis of these differences, and as will be seen, it was soon discovered that for the most part the differences in appearance were optical illusions.

The first samples examined were taken from a reversed badger-face sheep which was very clearly marked. A strip was cut from the side, passing across the division from the black side of the coat to the white ventral surface. It was possible to remove from this strip for analysis black and white samples that had grown on areas separated by only a few centimetres. The fineness of the wool fibres was determined first by the gravimetric method described

*Roberts, J. A. Fraser, and White, R. G., 1930. "Colour Inheritance in Sheep IV. White Colour, Recessive Black Colour, Recessive Brown Colour, Badger-face Pattern, and Reversed Badger-face Pattern." Jour. Genet., **22**, pp. 165–180.

in a recent paper.* It was found that there was no significant difference, and microscopic measurements of diameter were then made in order to eliminate the possibility that, although the number of centimetres weighing a milligram was the same in both cases, there might be a difference in density between black and white wool fibres that would in this case be reflected by a difference in diameter. The results were as follows—

Table I
Sheep No. 22 (1930)

	Fineness cms per mg	Diameter—μ			Length—cms		
		Number of Fibres Measured	Mean	Standard Error	Number of Fibres Measured	Mean	Standard Error
White wool	174	80	25	±0 55	179	8·0	±0·14
Black wool	177	80	25	±0 57	168	7 7	±0 14

It is clear, therefore, that there is no difference between the black and the white wool fibres as regards their dimensional attributes

In this particular fleece the white areas contained a considerable proportion of kemp which, as previously explained, seemed to be either lacking or very different in the black areas

Kemp determination,† however, gave the following results—

Table II
Sheep No. 22 (1930)

	Percentage Kemp by Weight	Number of Kemp Fibres per gram of Sample
White wool	23 5	2,140
Black wool . .	25 8	2,430

The difference in the proportion of kemp is not significant, and it is doubtful whether the greater number of black kemp fibres per gram is significant either. In general, treating the samples as being composed of kemp and non-kemp fractions, there is no difference, or only a very slight difference, between the black and the white wools

When the black and the white kemp fibres had been sorted out there appeared to be to the naked eye a most striking difference in their thickness The white fibres examined against any background looked much coarser than the black ones. Measurements were accordingly carried out on both types of fibre. Weight per fibre was calculated from the data in connection with the previous table, and lengths were measured directly. In order to obtain an estimate of the thickness of the kemp fibres the following technique was employed. Approximately a quarter of an inch was cut from the

*Roberts, J A Fraser, 1930 "Fleece Analysis for Biological and Agricultural Purposes I The Average Fineness of a Sample of Wool" Jour Text Inst, **21**, pp T127–T164

†An account of kemp analysis and illustrations showing the macroscopic and microscopic characteristics of kemp were published in the *Journal of the Textile Institute*, **17**, pp. T274–T290, 1926.

middle of each fibre; these portions were prepared for microscopic examination and two measurements were made on each portion, one at the thickest point, the other at the thinnest point. It was hoped in this way to avoid unconscious bias in the selection of a point at which each fibre should be measured, and also the differences between the thickest and thinnest points along each portion, when calculated on a percentage basis, gave a certain rough measure of the variability in diameter of the fibre. The results were as follows—

Table III
Sheep No. 22 (1930)

	Weight per Fibre mgs	Length—cms.			Diameter—μ			Percentage difference between thickest and thinnest place measured on each fibre	
		Number of Fibres Measured	Mean	S.E.	Number of Fibres Measured	Mean	S.E.	Mean	S.E.
White kemp fibres	0·112	78	3·6	±0·08	90	105	±2·5	19·9	±2·48
Black kemp fibres	0·106	78	3·5	±0·09	90	67	±1·9	18·1	±1 47

It will be seen that there is a considerable difference in diameter, but that the length of the fibres does not differ appreciably. In contrast with this the mean weight of the black kemp fibres was almost as great as that of the white kemp fibres, so that there is a definite suggestion in this case that a structural distinction exists between the two sorts of fibre. This difference is further discussed at the end of this paper. The variability of the individual fibres, roughly estimated as described above, did not differ appreciably for the white and coloured fibres.

If kempy sheep are examined it will be found that there is a strong suggestion that the kemp on the ventral surface is coarser then the kemp growing over the body generally. Although the black and the white samples in the present case were taken from areas that were comparatively close together, nevertheless the white sample was taken from an area more ventral than the black sample, and it is probable that the line of colour division more or less corresponds to the dividing line between the general fleece and the belly wool. It is impossible to exclude the possibility that the difference in coarseness of the white and the black kemp in the case of this sheep might be partly, or even wholly, due to this difference in the position of the areas from which the samples were taken. It is to be noted, however, that the disproportion between fibre weight and diameter still requires an explanation. A second series of samples was therefore examined, in this case taken from the same area on a badger-faced sheep. In the badger-face the ventral surface is black and the sides white, as contrasted with the reversed badger-face, in which the sides are black and the ventral surface white. The line of division between the areas occupies approximately the same position in each case. It was decided not to carry out measurements on the wool owing to the definiteness of the result given in the first table. The results as regards the kemp were as follows—

Table IV
Wensleydale × Welsh Badger-face

	Percentage Kemp by Weight	Number of Kemp Fibres per gram of Sample
White wool	32·6	4,270
Black wool	45·8	4,140

The difference between the percentage by weight of white and black kemp respectively is well marked, although as regards the number of fibres per gram of wool the difference is small. Measurements on the individual kemp fibres were carried out in the same way as with the previous samples, the results being as follows—

Table V
Wensleydale × Welsh Badger-face

	Weight per Fibre mgs	Length—cms.			Diameter—μ			Percentage difference between thickest and thinnest place measured on each fibre	
		Number of Fibres measured	Mean	S.E.	Number of Fibres measured	Mean	S.E.	Mean	S.E.
White kemp fibres	0·079	40	2·3	±0·10	39	125	±4·8	17·9	±2·27
Black kemp fibres	0·126	42	3·0	±0·17	41	117	±4·8	15·2	±2·27

The difference in structural characteristics is again well marked. The black kemp fibres are very much heavier than the white. As regards their length there is a significant difference, but as regards diameter the black fibres are actually slightly finer than the white ones, this difference, however, not being significant. There is no significant difference in variability. The differences in length are not nearly sufficient to account for the differences in weight. Once again the relation between diameter, length, and fibre weight is quite different in the two classes of kemp Considering both sheep together, when the white area is more ventral, the weight of the kemp fibres is approximately the same but the average diameter of the white fibres is greatly in excess of that of the black. When the black area is more ventral, the diameters are approximately the same but the weight of the black fibres greatly exceeds that of the white ones. The differences observed, therefore, in the two cases depend upon two factors, in the first place a difference due to the position of the sample, and secondly a difference in the relation between length, diameter, and weight in black and white kemp fibres respectively.

In ordinary white Welsh sheep it is not uncommon to find patches of red kemp. In such patches some of the kemp fibres are white, others pigmented. A sample of this type was examined, and measurements were made on the red and the white fibres growing on the same area. The results are given in the following table—

Table VI
Sheep No. 98 (1928)

	Weight per Fibre mgs.	Length—cms			Diameter—μ			Percentage difference between thickest and thinnest place measured on each fibre	
		Number of Fibres measured	Mean	S.E.	Number of Fibres measured	Mean	S.E.	Mean	S.E.
White kemp fibres	0·047	104	2·2	±0·06	90	78	±2·3	25·7	±1·64
Red kemp fibres .	0·063	104	2·5	±0·04	90	94	±2·0	21·2	±1·42

In this case the red kemp fibres have a greater diameter than the white ones, and also a slightly greater length, but once again the relation between length and diameter on the one hand and fibre weight on the other is different for the two types. During the course of analysis it was noted that there were

present a number of kemp fibres much finer than the rest. These were mostly white, and it is in all probability this fact that accounts for the difference in diameter observed as between the two classes of kemp fibres growing on the same area. The difference in variability is once again slight.

In view of the finding that when black and white kemp fibres are of the same diameter the weight of the black ones is greater than that of the white, or alternatively that when the weight per fibre is approximately the same the diameter of the white fibres exceeds that of the black, an attempt was made to determine the structural basis of this difference. There appeared to be two possibilities. The first was that the coloured fibres were heavier in proportion to their size because they contained a larger proportion of cortex and a smaller proportion of medulla than the corresponding white kemp fibres. On the other hand it might be thought possible that the masses of pigment granules in the cortex and medulla, particularly the latter, in the case of the black fibres, might cause an appreciable difference in weight. Of these two hypotheses the second did not seem very probable, especially in view of the very large differences found. In addition a certain number of measurements were carried out on the kemp fibres of sheep 22 (1930), using micrometer calipers. It will be recalled that microscopically the diameter of the white fibres considerably exceeded that of the black. The micrometer measurement gave slightly larger values for the black fibres. It is to be noted that micrometer calipers compress the fibre and would probably almost obliterate the medulla.

It is very difficult to examine black fibres microscopically, because the pigment granules are present in such dense masses that observation by transmitted light becomes almost impossible. Accordingly the coloured kemp fibres were bleached, and it was found that for complete bleaching it was necessary to use concentrated perhydrol of 100 volumes, made alkaline with ammonia. The fibres were bleached in this way, washed, stained with picro-formol, and prepared for microscopic examination. As it is possible that this rather severe procedure might alter the size of the fibres, the corresponding white kemp fibres were subjected to the same treatment Portions from the middle of each fibre were prepared in the same way as that described above, but in this case measurements were made at five points along the length of each portion, an attempt being made to space out these points as evenly as possible. The total diameter of each fibre was measured at each point and then the diameter of the medulla at the same point. The findings for the five points were averaged for each fibre and the results expressed as the percentage of cortex relative to the complete diameter of the fibre. The following table gives the results for the Wensleydale × Welsh samples. In this case, as shown in Table V, the total diameter of the white and black kemp fibres was not appreciably different, but the weight of the black fibres greatly exceeded that of the white.

Table VII

Wensleydale × Welsh Badger-face

	Number of Fibres Measured	Percentage Cortex	Standard Error
White kemp fibres	20	9	±1·06
Black kemp fibres	20	14	±0·82

In the case of sheep 22 (1930), as shown in Table III, the weights of the black and white kemp fibres were very similar, but the white kemp fibres greatly exceeded the black ones in diameter. The result of the measurements was as follows—

Table VIII

Sheep No. 22 (1930)

	Number of Fibres Measured	Percentage Cortex	Standard Error
White kemp fibres .. .	15	7	± 0.39
Black kemp fibres	15	57	± 2.27

It is clear, therefore, that black kemp fibres have a relatively much greater thickness of cortex than have white kemp fibres.

CONCLUSIONS

(1) The apparent difference in fineness of wool fibres in the case of coloured and white wools is not real.

(2) In kempy wools the difference in appearance between the white and coloured samples is very striking, but for the most part this difference too is unreal.

(3) There is, however, a difference between coloured and white kemp fibres. In proportion to their weight, coloured kemp fibres are finer than white ones. This difference is due to the fact that there is a larger proportion of cortex in coloured kemp fibres than in the white. It must be emphasised, however, that the smaller diameter sometimes found in the case of black kemp fibres could only account for a small part of the large apparent difference when the kempiness of the sample is judged by eye.

We wish to express our thanks to Miss M. Gurney, Miss D. Nicholson, and Miss M. Scheerer, who carried out a number of the measurements.

37—THE FORMATION OF "DIAMOND SPOT" STAINS BY MILDEW FUNGI

By Leslie Douglas Galloway, M.A.
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In fabrics exposed to damp conditions it is not uncommon to find that coloured mildew stains develop in more or less definite squares, the diagonals of which correspond to the directions of warp and weft. In some instances the shape is so clear cut that the name "diamond spot" has been given to it

In spite of its peculiar appearance, which frequently gives rise to the impression that it is due to some cause other than mildew, "diamond spot" has received little attention in textile or mycological literature. Broughton-Alcock,[1] in an account of his investigations on canvas deterioration in Malta, mentions the diamond shape of the spots, but gives no explanation beyond regarding it as a characteristic of the fungi concerned, which he found to be *Stemphylium* and *Macrosporium*. Ramsbottom[2] gives a brief summary of Broughton-Alcock's paper. Thaysen and Bunker,[3] in two unpublished reports quoted by courtesy of the Fabrics Co-ordinating Research Committee of the Department of Scientific and Industrial Research, describe the examination of a "diamond spot" fungal growth on tentage received from Palestine. They failed to reproduce the diamond-shaped stains under laboratory conditions, and concluded from their experiments that this peculiar shape was not a characteristic of either the fungus or the cloth, but depended on environmental conditions such as moisture.

Fig. 1
"Diamond Spot" on jute hessian conditioning cloth

Among samples of mildewed cloth received at the Shirley Institute, "diamond spot" formation has been rare. This, as will be shown later, is probably because such formation necessitates a higher moisture content than cotton goods usually attain to even in the worst storage conditions. One of the best examples received was from an outbreak on jute hessian used for "cloth" conditioning of yarn (Fig. 1). Here the fungus responsible was one with a darkly pigmented mycelium, and had caused very marked tendering in the affected areas. A less well marked example, caused by *Aspergillus terreus*, occurred on a cotton cloth returned from abroad on account of mildew.

Attempts to reproduce the "diamond spot" type of stain under laboratory conditions on pieces of sterilised cloth brought out the following points—

(1) The diamond shape could be obtained with all the organisms tested, which included *Cladosporium*, *Helminthosporium*, *Aspergillus niger*, *Asp. terreus*, and *Fusarium*. The diamond was best defined, however, with the organisms that stained by virtue of a dark pigmented mycelium (e.g. *Cladosporium*), so that the stain extended to the limit of growth. Poorer results were obtained with the *Fusarium*, the pigment of which diffused outwards, and with *Asp. niger*, where the coloured spores did not extend to the margin of fungal growth.

(2) Diamond formation occurred only when the cloth was thoroughly damp Keeping at relative humidities of 87%, 92%, and 100% was not sufficient, but cloth wrung out by hand, placed several layers deep in a Petri dish, sterilised and inoculated, and then incubated in a saturated atmosphere, gave very successful results Cotton duck with regains of 30–50% gave no indication of an optimum between these limits.

(3) It was at first thought that a loose weave would be essential. This is not so, however, and the best reproduction of "diamond spot" was obtained with a closely woven poplin (Fig. 2)

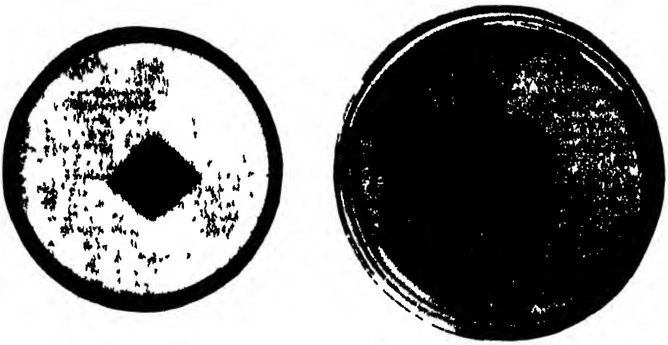

FIG 2

Growth of *Cladosporium*, left, on poplin, right, on a culture medium.

"Diamond spot" thus does not appear to be a characteristic of any particular organism, and the most obvious explanation is that it depends on the weave of the cloth. Growth starting from a centre of infection in a damp cloth naturally extends more rapidly along the warp and weft than across the open spaces. An equal rate of growth along warp and weft being assumed, growth starting at the point O in Fig. 3 would reach points a_1, a_2, a_3, etc., on the warp at the same time. It would also reach these points by alternative routes, indicated for a_3 by the dotted line. This would explain the diamond formation. In practice the diamonds may overlap and will, of course, differ in size according to their times of growth. Irregular shapes, such as those shown in Fig. 4, which are tracings from stains on the hessian shown in Fig. 1, are thus formed.

As an indication of this mechanism, an attempt was made to produce diamond formation by inoculating an artificial cloth structure. Of several methods tried, the following was the most satisfactory—

A plaster of Paris disc 3⅜ in. in diameter was prepared, a Petri dish being used as a mould, and saw cuts about ⅛ in. deep and ¼ in. apart were

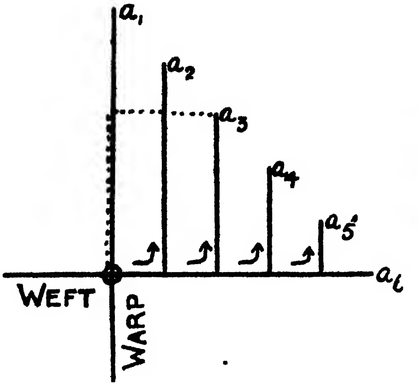

FIG 3

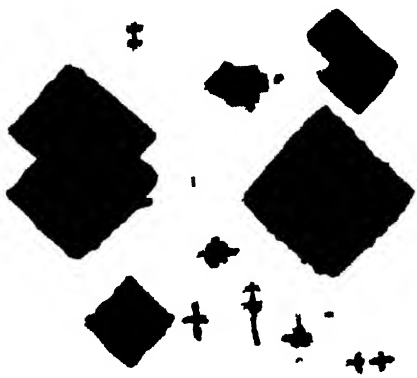

FIG 4

made to represent warp and weft. The plaster disc was placed in a Petri dish and sterilised in the autoclave, it was then cooled and a melted agar medium (Dox's agar) was poured on in sufficient quantity to fill the grooves. Finally the disc was inoculated at the centre with spores of *Cladosporium herbarum* and incubated at 25° C. in a saturated atmosphere. A typical "diamond spot" was formed, Fig. 5 being a photograph of the disc after ten days' growth

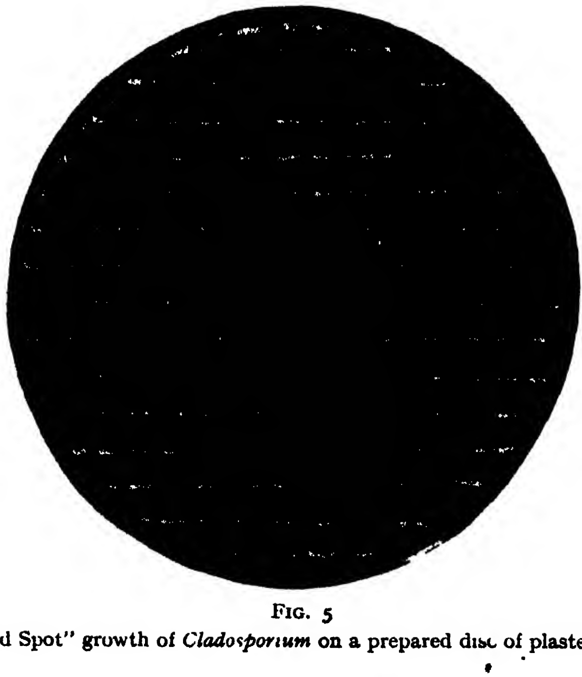

FIG. 5
"Diamond Spot" growth of *Cladosporium* on a prepared disc of plaster of Paris.

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38—COMPARISON OF SOME FABRIC TESTING METHODS

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INTRODUCTION

The properties of fabrics may be divided into two classes (1) characteristics governed by the dictates of fashion, artistic, or hygienic considerations, (2) characteristics governed by durability or ability to stand wear and tear in service. Fabrics of the latter class are frequently sold to specification, but there is difficulty in specifying any means of testing the probable behaviour of any fabric in use. Many different types of test have been proposed, but the tensile strength is the one usually specified as being a criterion of the quality of the material. It is generally stated that the figure for tensile strength may not bear any established relation to the serviceability in use. This need not be a disadvantage if the specified strength is based on experience of the suitability of the fabric of the specified structure. Possibly this is the case in a good many instances but not in the case of specifications for new materials or new uses. There is a need for a laboratory wear test which would give a quantitative estimate of the probable behaviour of a fabric under the stress and strain of wear.

The present work was undertaken in order to compare the results by various methods of fabric testing with actual service behaviour, which does not appear to have been done before with linen fabrics. It is probable that for very specialised uses, individual tests may be required, but there are many fabrics in which the type of wear experienced is common, e.g. (1) household linens, dress materials, and all washable fabrics, in which resistance to laundry wear is one of the most important properties

(2) Canvases, ducks for tents and coverings, which are not washed but have to withstand much friction with hard surfaces.

The results to be discussed deal only with one type of fabric, viz., plain linen woven from bleached 2½-lb. dry spun line yarn such as is very commonly used in the manufacture of roller towelling. Samples were prepared from a constant lea of yarn, spun with various twists and woven with varying ends per inch warp or weft. These materials were all given the same treatment in finishing and were then twice laundered at a public laundry, and subjected to the various laboratory tests. Pieces of the same materials were also repeatedly laundered until the first signs of wear appeared, the number of launderings being taken as a measure of the comparative life in service. Similar work is in progress with other classes of washable materials.

These sample cloths are abnormal inasmuch as in most cases the same yarn is used as warp and weft. Usually linen cloths are woven with a weft finer and weaker than the warp. This, however, introduces two further factors in the specification of the cloth structure and so to this extent complicates any attempts at interpreting cloth test results in terms of the cloth structure and yarn properties. It appeared that by working with series of samples of

this simplified construction, it might be possible to infer, with greater certainty, the relative effects due to the cloth structure. Most previous work has concerned the comparison of typical available cloths, involving differences in yarn counts, yarn settings, and finishes, so that direct inference of effects is often impossible.

Another difference which should be borne in mind is that, unless otherwise stated, these tests were made on cloth after being finished and twice laundered, whereas most recorded work on cloth testing concerns the results of cloth in the finished state. It is known that the method and nature of the finish has a decided effect on the test results, so it was considered desirable to have all the samples in a uniform state in this respect, and in the state in which the cloth is used rather than that in which it is sold.

EXPERIMENTAL DETAILS

Materials

The cloth was woven from $2\frac{1}{4}$-lb. dry spun line yarn, bleached HHD ($\frac{5}{8}$ white); in most cases the same yarn was used both for warp and weft, but in some few cases the same lea weft was used spun with varying twists The range of samples included yarns spun with six different twist factors woven as warp and weft in a constant weave; with several yarn twists cloth was woven with a constant number of warp ends per inch with varying number of weft ends per inch, and vice versa. The samples were then given a wash finish, all being treated alike, consisting of a sour, dip, blueing, widthing, 12 hours' beetling followed by a wash and a further 1 hour's beetling, and then lightly calendered. Several yards of each were then twice laundered in a public laundry, all being treated together by the methods usually employed for roller towels, and this material was used in the tests to be described. The finishing treatment adopted was that considered suitable for the cloth of the average weave, so that more open weaves were more and closer weaves less heavily finished than would be normally the case.

Testing

All the samples were conditioned in a room at 67° F., 75% relative humidity, analysed to determine the structural characteristics, and tested by various methods. "Dry" tests were made on the cloth in the air-dry condition in the above room, and also "wet" tests were made after soaking the specimens in cold water for 30 minutes.

The structure of a fabric made from given yarn can be expressed quantitatively in various ways, such as ends per inch warp and weft, weight in ounces per square yard, thickness, compactness (density of cloth), and crimp or percentage outcome of the warp and weft yarn. Some of these figures refer to the cloth as a whole, others to the yarns in separate directions, and the figures are related to each other in various ways. Each method of expression may have its own particular convenience in discussion of the behaviour of the cloth in different circumstances.

The ends per inch and the weight per square yard were determined in the usual manner to obtain a fair average. The thickness was measured with a micrometer dial-gauge, scale divided into 1/100ths. of a millimetre, having a large base plate and an upper plate with spring loading. In the instrument used this plate was $\frac{5}{8}$ in. diameter and the load on the plate 2 lb. These conditions were kept constant and a uniform practice adopted of lowering the plate gently into contact with the cloth. The average of 20 readings spaced over the cloth was taken.

The compactness or density of the cloth is a method of expressing the average closeness of weave and the extent of compression in finishing. It is the ratio of the weight of fibre in a given piece of cloth divided by the volume of the cloth contained between the two surface planes.' It is frequently estimated from the weight per unit area and the average thickness, but as the latter measurement is somewhat arbitrary, depending on the pressure applied, a direct method has been employed. This method is an adaptation of a method previously described for measuring the average diameter of yarns.[1] Several 2-in. squares of cloth are cut from the cloth and weighed. These are soaked in a light mineral oil for several minutes and the excess oil blotted off between sheets of filter paper. This oiled cloth is then laid on a sheet of glass and vaseline smeared over the surface and scraped off flat with a flexible steel blade. The piece is reversed and the other side treated similarly. In this way the fibre is waterproofed and all air spaces between the fibres and the yarns are filled with oil and vaseline. These pieces are then inserted in a volumeter (Armstrong's type) connected to a burette, by means of which the external volume of the treated cloth can be measured, and so the density of the cloth calculated. With a little experience the method is found to be capable of giving consistent results.

The yarn crimp expressed as percentage outcome is measured by cutting a strip of cloth in the warp or weft direction 10 in. in length and measuring the length of a number of the single yarns after laying out and straightening out in contact with a scale. The figure indicates the extent to which the yarn is corrugated in the cloth due to the bending over and under adjacent yarns in the transverse direction.

The Breaking Strength and Extension was measured on a Goodbrand machine (maximum capacity 1,000 lb.), rate of traverse 20 in. per minute, 7 in. between the jaws. The specimens were cut 2½ in. wide and frayed down to 2 in., and then the total number of threads counted in order to calculate as accurately as possible the strength per single thread. Twelve warp and twelve weft tests were made for each cloth in most cases; use of the tension motion supplied with the machine was found to aid considerably in obtaining consistent results, particularly in the case of the stretch.

The Bursting Strength was determined on the Jumbo-Mullen tester in the standard manner, with 5 in. between breaks, and the average of 20 breaks was taken.

The Impact Strength or work to break was measured on a Goodbrand ballistic testing machine. Specimens were cut 15 in. by 1 in. and frayed down to ½ in. in width and the total number of threads counted. Six warp and six weft tests were made for each cloth. In all the tests the pendulum was released from a fixed height.

The Tear Strength was measured on the Goodbrand cloth testing machine. Specimens were cut 7½ in. by 3 in. and then two longitudinal cuts were made 1 in. apart and 6 in. long. The central tongue was folded back and the end fixed in one jaw, and the two side pieces were fixed in the other jaw. In order to keep the conditions uniform throughout, the maximum strength recorded during the tearing of the cloth for a distance of ½ in. was taken. Five tests were made in each direction for each cloth. When the warp threads are parallel to the central cuts, the weft threads are broken and so give a tear "across weft" and vice versa. This is on the same lines as the tongue tear test described by Turner,[2] but with rather smaller specimens.

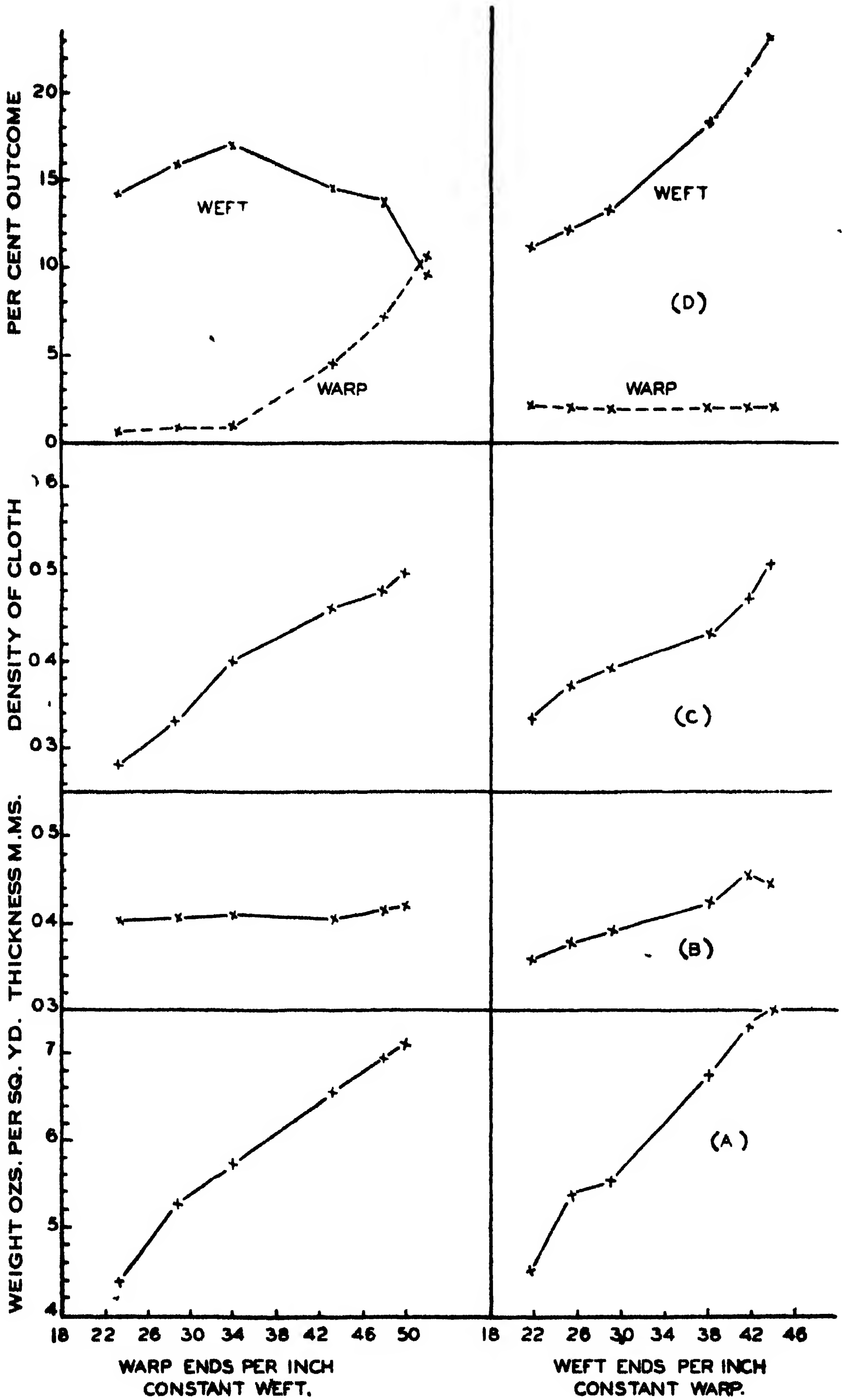
PER CENT OUTCOME
20
15
10
5
0
WEFT
WARP
(D)
DENSITY OF CLOTH
0 5
0 4
0 3
(C)
THICKNESS M.MS.
0 5
0 4
0 3
(B)
WEIGHT OZS. PER SQ. YD.
7
6
5
4
(A)
18 22 26 30 34 38 42 46 50
18 22 26 30 34 38 42 46
WARP ENDS PER INCH
CONSTANT WEFT.
WEFT ENDS PER INCH
CONSTANT WARP.

FIG. 1

The Wear Test was carried out on the cloth wear testing machine previously described in another paper.[8] Specimens were cut $2\frac{1}{2}$ in. in width and frayed to 2 in. and fixed in jaws 7 in. apart under a fixed tension of 15 lb. Five warp and five weft tests were made for each cloth. The wear was caused by the to and fro movement of the top end of the cloth over a distance of 4 in. whilst in contact with a carborundum surface, and the result is expressed as the number of rubs to cause breakage.

Resistance to Laundry Wear was tested on a selection from the same cloths as was used in the previous tests. Four 30-in. lengths of each sample were hemmed and all were repeatedly subjected to the full laundry process in a public laundry. The samples were treated together each time and given the usual treatment for soiled roller towels, which is one of the most severe processes used. The samples were examined at intervals of 20 launderings and records kept of the weight, length, and width of each piece, together with notes of damages or wear. This was continued up to 160 launderings, when most of the different cloths showed some sign of wear. Holes and other damages such as torn selvedges or hems were very few; in practically all the cloths wear was first shown by the breaking of one or more warp threads causing a series of holes along lines parallel to and at a short distance in from each selvedge, the centre of the cloth remaining free from actual holes, although it had become thinner and lost in weight. This kind of wear is very frequently evident on damask cloths, but it appears that the same effect is typical of pure laundry wear on plain woven hemmed pieces. For the present purpose it is necessary to reduce the results to a quantitative basis for comparison with other tests. The most definite and simplest method is to take the number of launderings at which the selvedge lines of wear first become apparent as the relative life of the cloth at the laundry. The cloth, of course, would be used for some time after this, but as there is no means of exactly determining when the cloth is unserviceable, this cannot be taken as an end point. The per cent. loss in weight when wear shows or the rate of loss of weight with laundering do not necessarily define the wearing power of the cloth, but a study of these figures is of interest and aids interpretation of the effects found.

The figures quoted are only comparative between the samples, as there would be a great difference in the life thus determined in different laundries.

The results obtained from the various tests are summarised in the tables to show in each case the effect of (1) closeness of weave, (2) yarn twist, (3) wetting.

CHANGES IN STRUCTURAL CHARACTERISTICS WITH CLOSENESS OF WEAVE

The results of the measurements of the various structural characteristics on the samples of twice laundered cloth with varying closeness of weave are summarised in Table I and shown graphically in Fig. 1 for the cloths woven from warp and weft of 1·7 twist factor. Only one set is graphed in order to save confusion, but inspection of the table will readily show that similar results are given by the cloths made from the other twist yarns. The cloths from 1·7 twist factor yarns are also of particular interest as these two sets of cloth were subjected to repeated laundering tests. These cloths were woven with either the warp or weft ends per inch constant; certain variations in shrinkage during finishing and laundering occur but the setting in one or other direction still remains approximately constant.

The results show several interesting differences between the changes in characteristics of the cloth on varying the closeness of weave warp or weft

Table I
Structural Characteristics, Twice Laundered Cloth

Ref No	Yarn Twist Factor: Warp	Yarn Twist Factor: Weft	Ends per Inch: Warp	Ends per Inch: Weft	Weight, Ounces per sq yd	Thickness mm.	Compactness (Density)	% Outcome: Warp	% Outcome: Weft
Increasing Warp Ends									
16CL	1·3	1·3	22·0	33·3	4·72	0·398	0·32	0·4	6·3
17			27·5	32·8	5·18	0·393	0·40	1·7	7·5
18			34·0	32·6	5·95	0·422	0·39	1·3	11·0
19			43·4	32·8	6·77	0·424	0·52	3·7	11·0
20			47·2	33·3	7·22	0·432	0·54	5·8	8·0
21			51·0	32·9	7·30	0·431	0·56	6·0	7·7
29	1·7	1·7	23·3	32·8	4·38	0·402	0·28	0·6	14·2
30			28·9	32·8	5·27	0·405	0·33	0·8	15·9
31			34·0	32·8	5·72	0·410	0·40	0·9	17·0
32			43·3	32·6	6·56	0·404	0·46	4·4	14·5
33			47·2	33·6	6·94	0·415	0·48	7·2	13·8
34			49·8	33·7	7·11	0·421	0·50	10·5	9·6
45	2·1	2·1	23·3	33·3	4·86	0·438	0·34	1·0	9·8
46			28·7	33·3	5·34	0·424	0·37	2·2	13·0
47			34·5	33·6	5·95	0·423	0·41	3·2	12·4
48			43·2	32·8	6·77	0·430	0·49	3·2	11·3
49			47·3	32·8	7·00	0·432	0·55	6·6	10·0
50			51·4	33·3	7·53	0·434	0·53	8·5	10·1
Increasing Weft Ends									
22CL	1·3	1·3	37·4	21·6	4·86	0·375	0·39	2·0	5·0
23			37·8	25·0	5·24	0·378	0·42	2·3	6·4
24			38·5	29·7	6·16	0·406	0·47	1·5	9·0
25			39·0	35·2	6·87	0·418	0·49	1·8	8·6
26			41·0	38·3	7·57	0·450	0·51	2·5	11·0
27			41·6	42·1	7·76	0·475	0·51	2·2	12·0
28			38·4	44·7	7·43	0·444	0·58		—
35	1·7	1·7	36·1	21·7	4·51	0·356	0·33	2·2	11·1
36			37·9	25·3	5·40	0·376	0·37	1·9	12·1
37			39·0	29·0	5·53	0·389	0·39	1·9	13·2
38			39·8	38·2	6·76	0·422	0·43	1·9	18·2
39			40·8	41·8	7·34	0·455	0·47	2·0	21·0
40			40·3	43·5	7·50	0·444	0·51	2·0	23·1
51	2·1	2·1	36·9	22·0	4·82	0·364	0·37	3·9	7·6
52			37·9	25·8	5·60	0·379	0·39	3·2	8·0
53			39·8	29·2	6·00	0·399	0·44	2·6	11·4
54			39·3	32·5	6·20	0·404	0·47		—
55			40·2	38·4	6·46	0·456	0·49	2·3	14·0
56			41·1	41·5	6·80	0·462	0·50	2·6	16·2
57			40·1	43·0	7·39	0·460	0·51	1·7	17·4

way. On increasing the number of warp or weft ends per inch alone, the weight of the cloth per square yard increases regularly and the graphs are well represented by straight lines. The rate of increase of cloth weight per unit area with increase of weft ends per inch on a constant number of warp ends per inch is, however, distinctly greater than in the reverse change of increasing the number of warp ends with a constant number of weft ends per inch. This is due to the fact that since the same yarn is used as warp and weft the weight per square yard depends only on the actual length of yarns in the cloth, i.e. on the per cent. outcome, as well as on the number of ends. The curves in Fig. 1 (D) show the changes in the per cent. outcome of the warp and the weft with increasing number of warp or weft ends, and these are very different. With constant number of warp ends and increasing the

number of weft ends per inch, the outcome of the warp yarn remains fairly constant, whereas the outcome of the weft yarns increases rapidly. With constant number of weft ends per inch and increasing the number of warp ends, the outcome of the warp yarns increases very slowly at first and then increases very rapidly; the outcome of the weft yarns increases slowly whilst the warp outcome is small, and then decreases whilst the warp outcome is increasing. Hence in the first case, with increasing weft ends, the effect is a clear increase in weight of cloth, but in the second case with increasing warp ends, part of the increase in weight is offset by a reduction in weight due to the shortening of the length of weft yarn held in the cloth.

A similar striking difference is shown by the thickness of the cloth on increasing either the warp or weft ends per inch alone. With increasing warp ends per inch the cloth thickness shows a very slight progressive increase. With increasing weft ends per inch the cloth shows a very pronounced and regular increase in thickness, Fig. 1 (B). The reason for this difference is plain if the structures of the cloths are considered in terms of the bending of the warp and weft yarns at each intersection. Theoretically with a cloth made from equal sized incompressible yarns, the cloth thickness may conceivably vary from three times the yarn diameter when one set of yarns are quite straight, to twice the yarn diameter when both sets of yarns are suitably corrugated; any variation between these limits is possible according to the yarn settings and the tensions applied in finishing.

The amount of bending is proportional to the per cent. outcome, so in the samples with increasing weft ends, where the warp outcome is constant, the regular increase in thickness is clearly due to the progressive increase in the bending of the weft yarn. In the samples with increasing warp ends, the changes in warp and weft outcome are small at first and then an increase in warp outcome which would tend to thicken the cloth is accompanied by a decrease in weft outcome, which tends to reduce the thickness of the cloth, and it so happens that these two effects approximately counterbalance each other and the thickness remains fairly constant. The main result is that in these laundered cloths, the thickness is mainly a function of the closeness of shotting.

The compactness or density of the cloth, Fig. 1 (C), increases regularly and at about the same rate, with increasing closeness of the warp or weft yarn. The density depends on the weight per unit area and the thickness, so this result is confirmed by the previous measurements. With increasing number of warp ends, an increasing weight per unit area is made into a cloth of approximately constant thickness and so the density increases. With increasing number of weft ends, the weight per unit area increases more rapidly than in the previous case, but the thickness also increases and so the rate of increase of density is approximately the same as in the previous case.

The results bring out very well the complex nature of considerations of cloth properties and behaviours. A change in the closeness of weave in one direction may affect the external characteristics (weight per square yard and thickness) in a different way to a change in the closeness of weave in the transverse direction. Again a change in the closeness of weave in one direction may have an effect on the internal structure (per cent. outcome) or lie of the yarns in both directions. For purposes of interpretation of the behaviour of cloth in strength and other tests, where the result must depend to some extent on the internal effect of one set of yarns on the crossing threads, consideration of the cloth structure in terms of outcome of the yarns is therefore likely to be of very great importance.

Table II—Mean Dry Test Results on Twice Laundered Cloth. Warp and Weft 2½ lb. Dry Spun Flax Line HHD

Ref. No.	Yarn Twist Factor		Ends per Inch		Breaking Strength Pounds		Per cent. Extension		Bursting Strength Pounds sq. in.	Impact Strength Inch pounds on 1 in. Strip		Tearing Strength Pounds		Resistance to Wear Rubs to Break	
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft		Warp	Weft	Across Warp	Across Weft	Warp	Weft
Increasing Warp Ends															
16CI	1·3	1·3	22·0	33·3	131·3	140·5	3·4	11·0	136·0	16·7	39·1			287	257
17			27·5	32·8	184·5	144·7	3·65	11·7	146·2	25·8	45·8			424	286
18			34·0	32·6	205·7	136·5	3·6	12·1	161·5	30·8	56·8			465	358
19			43·4	32·8	235·8	162·7	5·36	12·36	221·0	62·6	59·2			794	564
20			47·2	33·3	264·5	173·3	8·14	11·64	277·2	75·6	57·3			951	643
21			51·0	32·9	326·2	187·2	9·26	10·5	333·5	78·0	58·4			1234	673
29	1·7	1·7	23·3	32·8	119·7	125·3						33·2	35·2	193	210
30			28·9	32·8	183·7	160·2						33·4	35·0	339	275
31			34·0	32·8	209·0	168·3						33·8	32·5	549	324
32			43·3	32·6	233·5	172·5						38·0	35·2	638	408
33			47·2	33·6	274·5	184·3						39·4	34·0	722	458
34			49·8	33·7	298·5	195·8						41·7	33·3	989	568
45	2·1	2·1	23·3	33·3	142·5	154·2	5·96	16·96	96·5	24·2	40·7	34·0	28·8		
46			28·7	33·3	174·5	165·0	6·84	18·16	122·7	28·4	49·8	35·7	30·3		
47			34·5	33·6	197·0	170·0	6·84	17·37	151·2	45·4	58·3	31·7	38·1		
48			43·2	32·8	214·2	177·0	8·93	18·44	226·2	65·7	61·8	32·2	33·0		
49			47·3	32·8	230·7	182·5	11·01	15·47	296·7	68·2	57·9	32·5	31·7		
50			51·4	33·3	275·3	186·1	12·2	16·67	327·2	78·5	55·2	35·0	32·5		
Increasing Weft Ends															
22	1·3	1·3	37·4	21·6	174·0	96	3·4	8·96	—	39·0	—			384	165
23			37·8	25·0	187·7	119·6	3·74	10·43	183·2	45·7	30·0			475	285
24			38·5	29·7	212·9	149·0	3·61	12·4	176·7	45·2	45·6			678	380
25			39·0	35·2	207·7	198·2	—	—	181·0	53·2	54·7			762	453
26			41·0	38·3	220·2	238·3	3·61	16·9	191·2	49·2	71·7			1060	597
27			41·6	42·1	217·5	254·4	3·6	16·3	203·6	52·8	81·6			1230	884
28			38·4	44·7	224·8	278·3	3·59	18·88	223·4	49·7	82·9			—	—
35	1·7	1·7	36·1	21·7	169·7	113·5						29·3	33·2	277	164
36			37·9	25·3	177·0	127·2						29·3	33·3	336	210
37			39·0	29·0	196·5	159·8						30·9	33·0	432	280
38			39·8	38·2	200·7	236						32·8	38·6	735	468
39			40·8	41·8	216·2	259·5						33·9	33·5	920	560
40			40·3	43·5	217·8	275·8						33·9	32·0	973	630
51	2·1	2·1	36·9	22·0	176·2	104·7	8·33	13·4	201·7	54·6	34·8	26·0	30·8		
52			37·9	25·8	188·7	125·8	8·33	13·7	199·5	59·0	46·3	28·5	30·5		
53			39·8	29·2	213·2	144·3	8·33	15·47	189·3	56·6	55·8	28·3	32·5		
54			39·3	32·5	211·3	159·5	8·93	16·97	206·5	57·9	54·7	34·5	37·4		
55			40·2	38·4	216·8	196·5	8·33	17·86	213·4	56·1	72·5	30·0	36·1		
56			41·1	41·5	218·3	239·2	7·74	19·0	236·7	63·1	76·5	28·8	34·3		
57			40·1	43·0	222·3	257·3	8·33	21·13	246·7	63·8	74·7	30·8	35·3		

DISCUSSION OF TESTS ON DRY CLOTH

The results of the tests carried out by the various methods already described on specimens of cloth in air-dry condition at 67° F., 75% R.H., are summarised in Table II, varying closeness of weave, and Table III varying

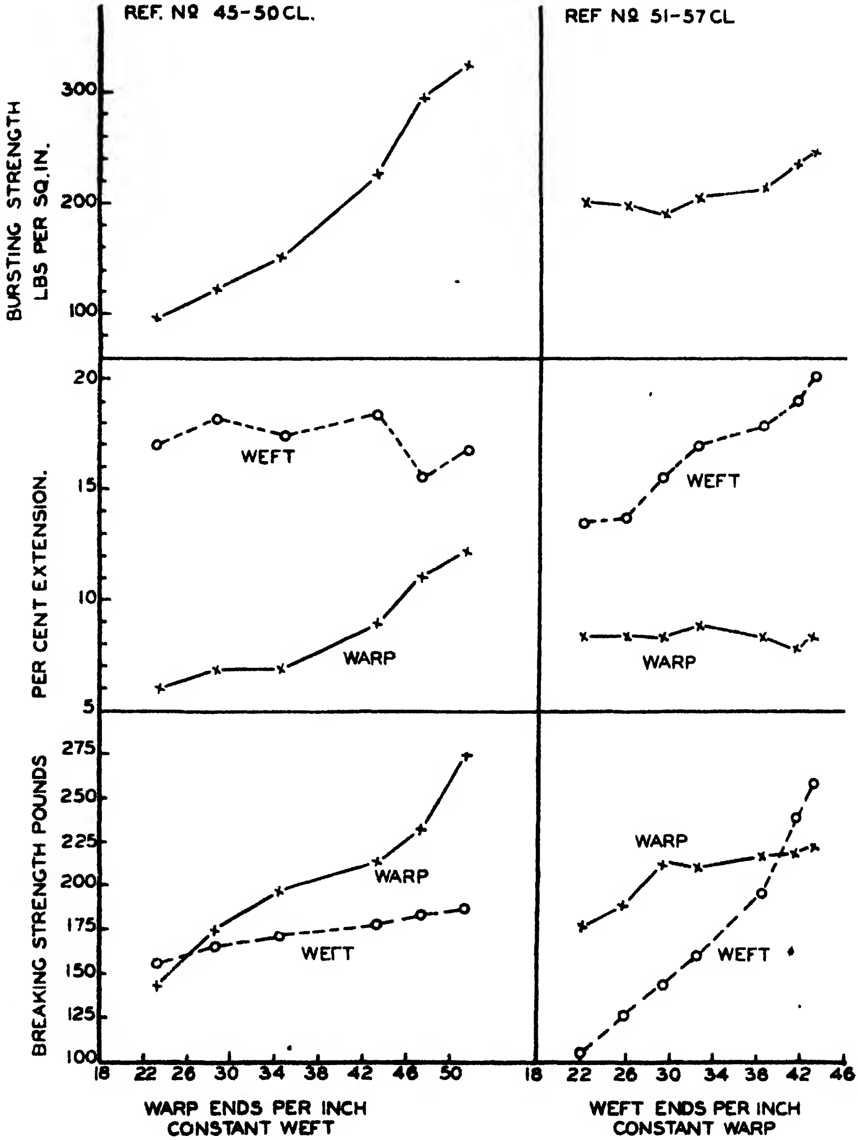

FIG. 2

twist of warp and weft. The nature of the variations can be appreciated better from the graphical representations in Figs. 2–5. Since the tests on the duplicate sets of different twists in Table II are in excellent agreement, only one set is graphed in each case to save confusion in the diagrams. In these graphs the test results are plotted as ordinates and the superficial

variants, closeness of weave, or the yarn twist factors as abscissæ. The graphs therefore show how the test machine results vary, and to some extent serve as a basis of comparison of the methods. In some cases it is more informative to consider the test results from other points of view. The results will first be discussed generally from the point of view of variation of test result with closeness of weave or yarn twist and then in detail with respect to the relation between test result and yarn property or cloth structure.

TEST RESULT AND CLOSENESS OF WEAVE

The test results in Table II are shown in Figs. 2 and 3. From inspection of the curves it is fairly clear that in tests where warp and weft specimens are tested separately, very similar changes in results with changing number of ends are shown by the warp specimens with increasing number of warp ends and by the weft specimens with increasing number of weft ends per inch.

In the tensile strength test, the breaking load increases with increase of the number of longitudinal threads in the test specimen gripped in the jaws. Over a certain range the breaking load appears to increase approximately in proportion to the number of ends, but beyond a certain point the increase in breaking load is more rapid. In the tests where the number of longitudinal threads gripped in the jaws is constant and the number of transverse threads is increased, the breaking load also shows a progressive increase which may be represented approximately by a straight line. According to previous writers this increase represents a contribution to the breaking load of the specimen by the transverse threads which are not gripped between the jaws. The tensioning of the specimen in the longitudinal direction is supposed to set up stresses in the transverse direction, so reducing the stress in the longitudinal direction and enabling the specimen to withstand a greater pull than it otherwise would. This will be considered in more detail later. It may be noted that the increase from this cause is greater when the transverse threads are weft (right-hand curve, warp) than when they are warp threads (left-hand curve, weft).

These curves as a whole clearly show that the result of a tensile strength test of a fabric is a composite quantity, contributed by the tensile strength of the individual yarns in the longitudinal direction, and part by the effects of the presence of transverse threads interlacing with the longitudinal threads. The latter is often described as a binding effect and will obviously depend on the extent and intimacy of the contact at the intersections, which will depend on the treatment received by the cloth. The tensile strength test is commonly employed as a specification test as a method of check on the quality of yarn employed in a given structure. This is obviously only approximately true and the result may vary with variation in finishing conditions.

In the curves for per cent. extension at break, the specimens with increasing number of longitudinal yarns show a very pronounced increase, whereas the specimens in which the number of longitudinal threads is constant whilst the number of transverse threads increase, show a fairly constant extension at break. The extension of a fabric is composed of two parts, the extension of the yarn and the straightening out of the corrugations, and the results are discussed from this point of view later. It may be noted here, however, that although the same yarns are concerned, by varying the cloth structure transverse to the direction of the applied tension, the breaking load may be affected without altering the extension at break. This means that

the extensibility per unit load is altered and also indicates that the extensibility of the cloth must be intimately related to the cloth structure irrespective of the extensibility of the yarn. This is also confirmed by the fact that in all these samples the extensibility is greater in the specimens with the weft

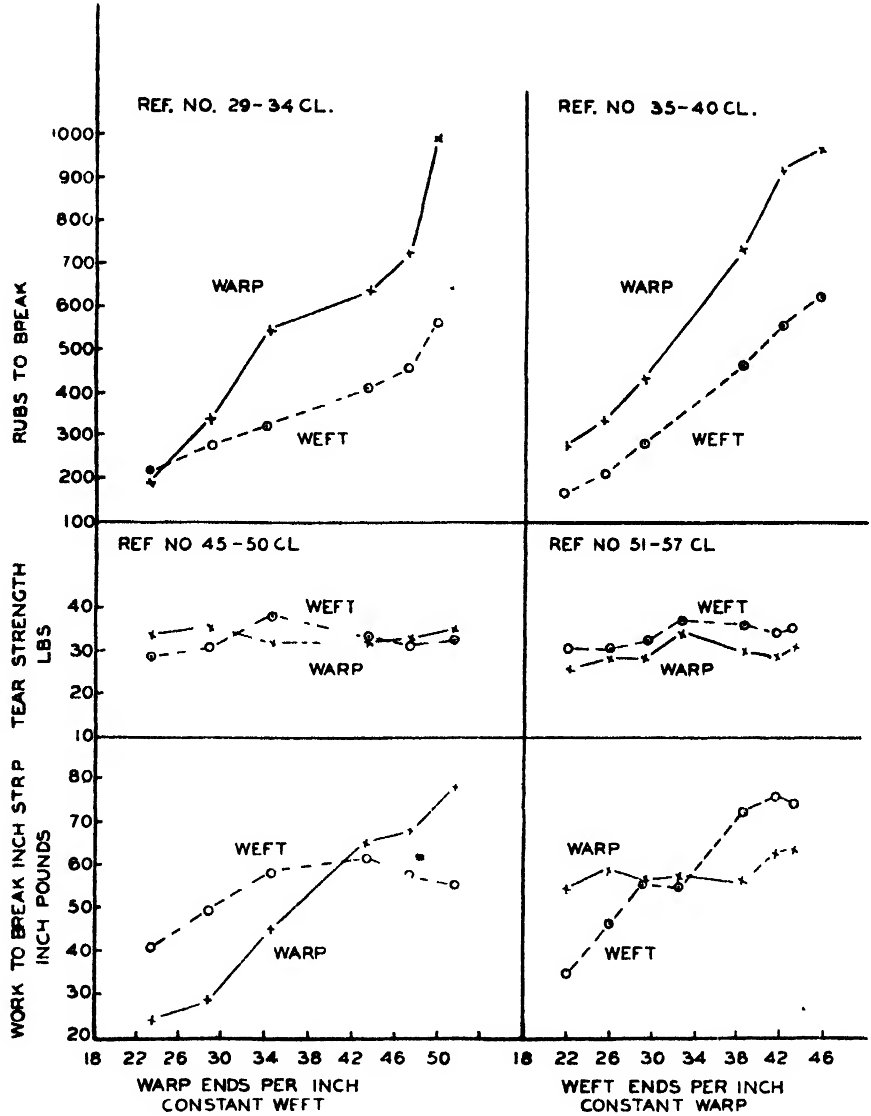

Fig 3

yarns in the longitudinal direction. This suggests a decided relation between the extension of the cloth and the crimp of the yarn in the cloth. Comparison of the extension curves and the curves for per cent. outcome in Fig. 1 (D) at once reveals a very striking similarity.

The results of the bursting test show very pronounced differences with variation in the cloth structure in the two directions. In the specimens with

increasing number of warp ends, the bursting strength increases very rapidly, and rather more than in proportion to the number of warp ends. With increasing number of weft ends, the bursting strength remains fairly constant over the greater part of the range, with a slight increase with the closest shottings. The two curves in fact are very similar to the corresponding curves for warp specimens in the tensile strength test. During the tests it was observed that in all these specimens, the bursts were practically all due to breakages of warp threads. Reference to the curves for extension of these fabrics shows that these cloth samples are much less extensible in the warp than in the weft direction. The application of pressure to the cloth through the rubber diaphragm causes it to bulge and so become extended. This places the yarns under stress, and naturally the greater part will be taken up by the less extensible threads. This therefore accounts for the breakages in the warp threads as being due to the low extensibility in this direction. The difference in warp and weft extensibility in these samples is so great that the bursting test merely develops into a test of the strength of the cloth in the warp direction. It is, of course, well known that fabrics always give way in this test in the less extensible direction and so the test is of no use as a means of comparison of different fabrics of very different constructions. In some cases, however, it may be used as a rapid and convenient test as it involves no special preparation of specimens, provided the above limitations are borne in mind.

The curves in Fig. 3, showing the change in impact strength or work to break with varying closeness of weave, show that the strength increases very approximately in proportion to the number of ends in the specimens in which these are varied. In the specimens in which the number of longitudinal threads under tension is constant whilst the number of transverse threads per inch is increased, some slight increase in strength is indicated at parts of the range, but over a greater part of the range tested, a fairly constant strength was obtained. The work to break cannot be calculated from the breaking load and the extension at break, as the load-stretch curve for a fabric is not a straight line. It is fairly obvious, however, from inspection of the three sets of curves, that the work to break results are intimately related to those for strength and stretch. Whilst the tensile strength test and the impact strength test would place warp or weft specimens in any one set in the same relative orders, they place the sets as a whole in different relative orders one to the other. It would appear from these results that this impact test offers some advantages over the tensile strength test as a test of the quality of the yarn composing the cloth specimens. The linear relation between strength and number of longitudinal ends in the specimen, and the approximation to a constant result with increasing number of ends transverse to a constant number of longitudinal threads both indicate that the test depends on the properties of the yarn and minimises the effect of binding at the intersections which is a marked feature of the tensile strength test.

In the curves for tear strength, the curves are marked "warp" and "weft," indicating that the tear takes place "across the warp" or "across the weft." The results show some fluctuations, but on the whole it is evident that the tear strength is fairly constant. It is therefore largely independent of the closeness of weave and must depend on the properties of the yarn. In the set of samples with increasing number of weft ends, the tear strength across the weft is consistently higher than that across the warp, but this is not

obtained in the second set of samples with increasing number of warp ends. Turner[2] found that high extensibility goes with low tear strength, but this is not consistently confirmed by these results. As he employed fabrics of normal construction, containing different yarns as warp and weft, it is possible that his conclusions were vitiated by some unconsidered factor arising from this. These tests are simpler to consider as the same yarns were used as warp and weft. The tearing action is local, the stress falling on the threads in turn, so that superficially the result should depend mainly on the strength of the single yarns. The stress falling on the yarn will not only depend on the extensibility of the yarns being torn, but also on the extensibility of the cloth in the transverse direction, that is, in the direction of the pull exerted on the tongue. A possible suggestion as to the relative tear strength of the warp and weft yarns in these samples would be that it depends on the state of compression of the yarns imposed by the finishing process, as well as on the spun structure. In these samples it has been shown that the weft yarns are the more corrugated (except in No. 34CL) and therefore would be the more compressed under the pressure of the calender rollers in finishing. Some irregularities would be expected as the compression would inevitably be variable between one sample and another, particularly if the moisture content varied to any extent.

The curves for resistance to wear or rubs to break show fairly consistent increases with increase of ends per inch, whether the specimens are rubbed with the warp or the weft under tension. Except in one sample, the specimens rubbed with the warp yarns under tension show a higher number of rubs to break than when the specimens are rubbed with the weft yarns under tension. There appears to be no obvious reason for this. At first sight it might appear that the test is simply one of mechanical wear by attrition, and as the same yarn is used as warp and weft, it might have been reasonable to expect that the result would have been practically independent of the direction of the rubbing. If this had been so, then the result would also have been dependent on the thickness of the cloth. Actually the result is dependent on the direction of stress during test, and is independent of the cloth thickness; whilst samples 29-34CL are of equal thickness, samples 35-40CL increase in thickness, and yet in each case the rubs to break increase very definitely. This therefore suggests that the rubs to break are dependent on the amount of fibre in the surface. Consequently anything which produces this result, such as closer weaving or flattening of the yarns by compression in finishing, should cause an increased resistance to wear. This actually is found to be the case, but still it does not appear to afford any explanation as to why the test will be greater in the warp or weft direction in different states of the cloth. This question has already been discussed to some extent in a previous paper,[3] when it was shown that considerations of the yarn crimp provided no explanation, but the state of compression appeared to be an important factor. This is very much in agreement with the present remarks, but the reason for the relative warp and weft tests is still indefinite. It is clear that the wear test result, whether tested with warp or weft under tension, varies with the structure of the cloth in either direction, and so either a warp or weft test would be sufficient for the comparison of the resistance to wear of fabrics in a similar state. The comparison of warp and weft tests, on the other hand, may prove of value in investigations relating to the relative compressions of warp and weft yarns in the fabric.

TEST RESULT AND YARN TWIST

The results of tests similar to those discussed above made on twice-laundered cloth in air-dry condition, made to a constant weave with warp and weft yarns of equal and varying twist, or with a constant warp and varying weft twist, are summarised in Table III and shown graphically in Figs. 4 and 5.

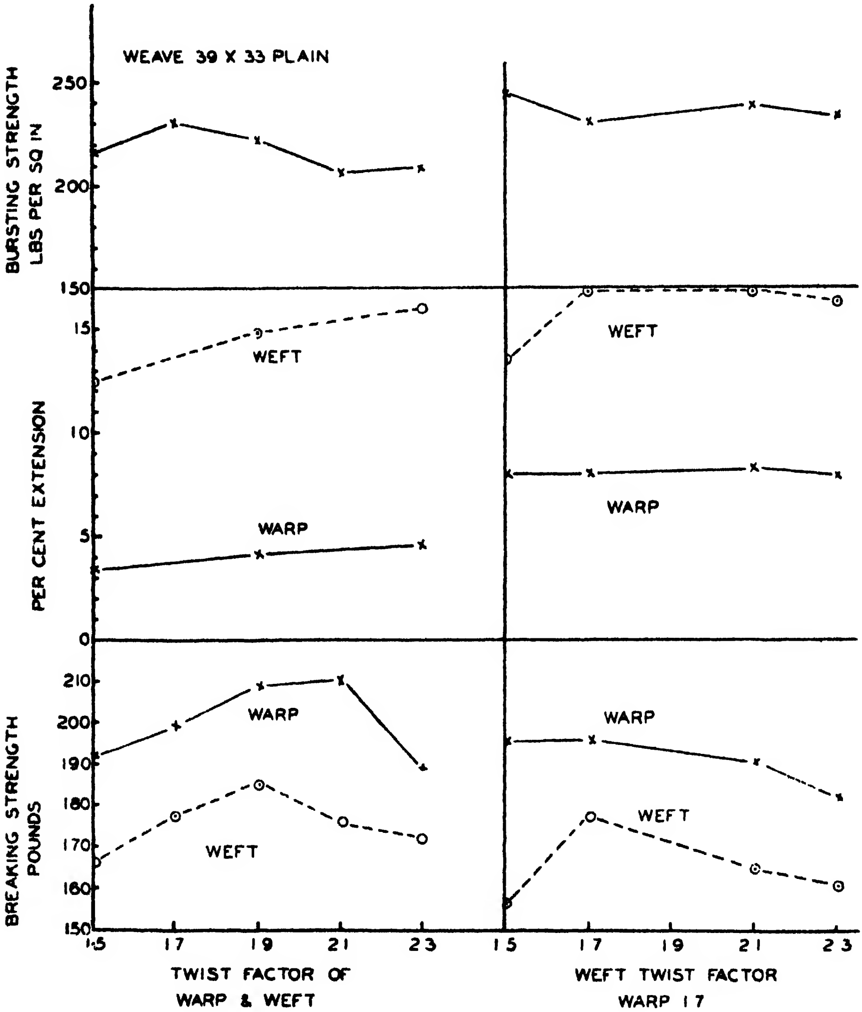

Fig. 4

(1) Varying Warp and Weft Twist

The breaking strength curves for warp and weft specimens both show a decided increase to a maximum followed by an equally decided decrease in strength. The warp strength appears to be a maximum between 1·9–2·1 twist factor, whilst the weft strength is at the maximum at 1·9 twist factor. The strength-twist curve for this yarn in the hank gave a sharp peak or maximum at a twist factor of 1·7. The strength-twist curves for the cloth are therefore very similar to those for the singles yarn, but with the maxima

at a higher twist. This confirms the previous conclusion that the cloth strength is directly related, but not entirely proportional, to the yarn strength. The shift in the twist factor to give maximum strength would then be attributable to a variation in the binding effect already discussed; the results would indicate a greater addition to the cloth strength by this effect with increasing twist in the yarn, and a greater effect on the warp than on the weft, which was also deduced in the previous discussion.

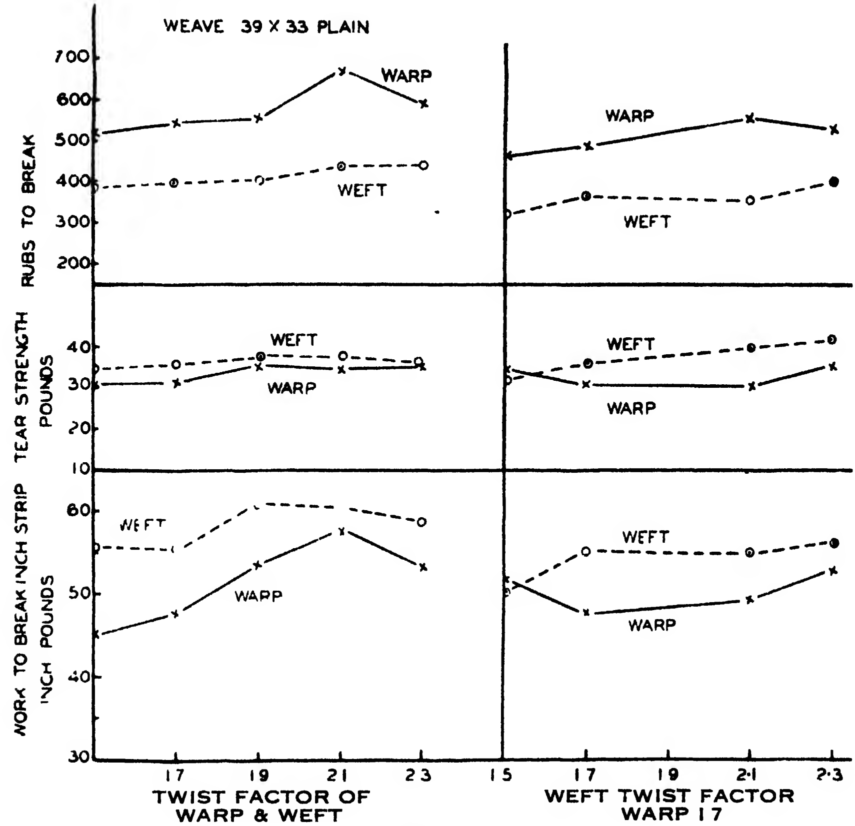

FIG. 5

As before, the weft extension of the cloth is much greater than that of the warp, and both show a small increase with increase in the yarn twist. The extension at break of singles yarn shows a similar increase with increase of twist (varying from 1·66 to 2·15% from T.F. 1·5 2·3). The previous discussion indicated a direct relation between cloth extension and yarn crimp. This result shows that the yarn extension also enters into the total result.

The bursting strength shows a maximum value at a twist factor of 1·7. As before the bursts were all due to warp breaks, owing to the low extensibility of the cloth in the warp direction. The bursting strength-twist curve is therefore a close replica of the strength-twist curves of the singles yarn, and again confirms the previous conclusion that the bursting strength test is simply an indication of the strength of the cloth in the less extensible direction.

The curves for work to break show maxima at the twist factors which gave maximum tensile strengths. The slight increase in extension with twist is

Table III

Mean Dry Test Results on Twice Laundered Cloth. Warp and Weft 2¼ lb. Dry Spun Flax Line HHD

Ref. No.	Yarn Twist Factor		Ends per Inch		Breaking Strength Pounds on 2 in. Strip		Per cent. Extension		Bursting Strength Pounds/sq. in.	Impact Strength Inch pounds on 1 in. Strip		Tearing Strength Pounds		Resistance to Wear Rubs to Break	
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft		Warp	Weft	Warp	Weft	Warp	Weft
Varying Weft Twist															
43CL	1·7	1·5	39·3	32·3	195 3	156·2	8·04	13·4	244·3	51·7	50·2	34·2	32·0	458	314
41		1·7	39·0	32·1	195 9	177·4	8·04	16·9	230·5	47·6	55·3	31·3	35·8	483	360
42		2·1	38·6	32·5	190·2	164·9	8·33	16·9	238·0	49·1	54·9	30·3	39·8	554	348
44		2·3	39·7	32·4	181·5	161·0	7·97	16·37	233·2	52·8	56·3	35·6	41·3	525	399
Varying Warp and Weft Twist															
58	1 5	1·5	38 4	33·2	191·7	166·5	3 44	12 53	216·4	44 9	55·7	31·0	34·5	514	386
41	1·7	1·7	39·0	32·1	199·0	177·4	—	—	230 5	47 6	55·3	31·3	35·8	544	395
59	1·9	1·9	39·1	33·5	209·0	185 5	4 14	14 86	222 5	53·6	60·8	35·2	37·7	550	400
54	2·1	2·1	39·3	32·5	210·5	175·5	—	—	206·5	57·9	60·4	34·5	37·5	670	432
60	2·3	2·3	39·8	33·4	188·3	172 2	4 61	16 03	208 2	53·3	58·9	35 0	35·3	589	436

Table V

Per Cent. Increase in Test Results on Wetting

Ref. No.	Yarn Twist Factor		Ends per Inch		Breaking Strength		Per cent. Extension		Bursting Strength	Impact Strength		Tearing Strength	
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft		Warp	Weft	Warp	Weft
Varying Weft Twist													
43CL	1·7	1·5	39·3	32·3	20 0	25 1	16·5	11 3	26·3	9·0	12·5	15·5	6·4
41		1·7	39·0	32·1	22·4	20·7	10·9	0·4	37·8	29·8	16·4	11·2	7·8
42		2·1	38·6	32 5	20 8	36·1	14·8	3·7	29·3	20·2	12·7	12·8	7·5
44		2·3	39·7	32·4	32 5	24 9	12 1	3·6	39·8	22·5	21 7	10·0	9·4
Varying Warp and Weft Twist													
58	1·5	1·5	38·4	33·2	3 7	20 1			53·0	12 5	18 3	10·4	11·0
41	1·7	1·7	39·0	32 1	12 9	15 7			37·6	29·8	18·2	11·3	8·0
59	1·9	1·9	39·1	33 5	27·5	5·1			31·9	39·0	16·5	6·6	14·8
54	2·1	2·1	39·3	32·5	23·5	12·2			33·1	21·4	14·5	11·0	12·9
60	2 3	2·3	39 8	33·4	17 7	6·6			36 5	19 2	12 9	10·9	21·3

Table IV—Per Cent. Increase in Test Results on Wetting

Ref. No.	Yarn Twist Factor		Ends per Inch		Breaking Strength		Per cent. Extension		Bursting Strength	Impact Strength		Tearing Strength		Resistance to Wear	
	Warp	Weft	Warp	Weft	Warp	Weft	Warp	Weft		Warp	Weft	Warp	Weft	Warp	Weft
Increasing Warp Ends															
16CL	1·3	1·3	22·0	33·3	15·5	26·4	30·8	5·9	13·6	59·9	13·8			168	87
17			27·5	32·8	2·8	22·8	28·0	8·2	29·6	35·9	6·6			85	107
18			34·0	32·6	13·1	33·8	38·9	5·0	49·5	57·2	15·1			150	112
19			43·4	32·8	21·1	18·7	50·8	3·9	48·9	9·6	11·1				
20			47·2	33·3	16·9	19·1	26·3	3·1	35·4	15·5	1·8				
21			51·0	32·9	10·9	5·1	31·1	4·8	18·5	13·9	5·6				
29CL	1·7	1·7	23·3	32·8	34·8	36·2						9·9	18·8		
30			28·9	32·8	9·1	19·5						16·8	25·8		
31			34·0	32·8	15·3	23·8						12·2	28·0		
32			43·3	32·6	34·9	43·4						6·0	18·5		
33			47·2	33 6	30·8	35·9						19·9	21·3		
34			49·8	33·7	23·8	25·1						11·1	18·0		
45CL	2·1	2·1	23·3	33·3	—	13·4	4·9	3·4	79·4	17·5	33·3	3·9	19·1		
46			28·7	33·3	3·4	3·9	4 5	1·7	86·5	56·4	27·5	2·9	42·0		
47			34·5	33·6	12·4	14·6	30 5	7 9	73 8	32·2	12·4	8·3	5·7		
48			43·2	32·8	36·3	13·2	23·5	3·0	56·6	14·3	5·4	33·5	27·2		
49			47·3	32·8	45·9	11·5	18·9	3·4	26·8	23·4	12·0	23·0	15·1		
50			51·4	33·3	26 9	29·7	26·9	2·0	18·4	29 3	13·6	30 8	17·9		
Increasing Weft Ends															
22	1·3	1·3	37·4	21·6	13·1	28·4	85 0	5·6	—	17 5	—				
23			37·8	25·0	13 8	13 8	43 2	5 5	69 5	6·9	1·3				
24			38·5	29·7	5·0	5·0	55 4	2·9	72·8	22 2	7·2				
25			39·0	35·2	11·3	11·3	—	—	68·5	16·3	9·2				
26			41·0	38·3	14·9	14·9	66·0	3·0	63·3	27·5	5 7				
27			41·6	42·1	12·7	12 7	62·7	2·6	46·2	4 0	12·3				
28			38·4	44·7	16·6	16·6	56·6	3·5	31·8	25·5	32·9				
35	1·7	1·7	36·1	21·7	14·4	14·6						23·9	14·9		
36			37·9	25·3	26·6	12·2						32 2	—		
37			39·0	29·0	20·6	17·7						31 6	10·6		
38			39·8	38·2	19·6	29 3						10 2	15·8		
39			40·8	41·8	13·4	23·8						8·4	20·4		
40			40·3	43·5	18·6	17·0						8·7	24·1		
51	2·1	2·1	36·9	22·0	16·0	28·8	7·3	—4·2	38·5	9·6	10 8	48·2	11 3		
52			37·9	25·8	17·9	14·9	10·8	2·4	51·9	10·5	26·2	28·0	22·4		
53			39·8	29·2	12·4	25·6	17·8	7·9	56·4	25·1	19·8	23·0	13·5		
54			39·3	32·5	16·9	18·8	6·8	—20·8	40·1	21·5	26·4	11·0	13·5		
55			40·2	38·4	24·5	27·5	25·0	3·2	35·2	42·2	11·8	26·1	11·8		
56			41·1	41·5	27·8	25·4	38·4	—	25·8	17·7	38·6	24·4	26·4		
57			40·1	43·0	31·2	20·6	32·0	4 1	14·2	10·4	35·0	28·7	29·8		

insufficient to counteract the decrease in strength beyond the twist for maximum strength. There is, however, a complete reversal in the relative warp and weft values, brought about by the great difference in the warp and weft extensions of the cloth. It is again clear that this impact test and the tensile strength test would both place either the warp or weft samples in the same relative order within their own group, but the two tests would give a totally different valuation to warp as against weft specimens. The result of the impact test is very clearly dependent on the extensibility of the cloth as well as on the strength of the yarn. This would tend to limit seriously the advantages previously deduced, and confine them to cases where the test was applied to cloths of similar extensibility. In this case the impact test would become classed with the bursting test as only giving strictly comparable estimates of quality on cloths of similar extensibilities. The same limitation of course does not apply if the impact test is used to measure the work to break as a criterion of the serviceability of the cloth, if in certain cases these factors have been demonstrated to be related.

The variation in tear strength with yarn twist is not very pronounced. As in one of the previous sets, the tear strength across the weft is consistently slightly greater than that across the warp.

As before, the resistance to wear is greater with specimens rubbed with the warp yarn under tension, and with both warp and weft specimens a definite increase in the rubs to break is shown with increase of yarn twist. This increase is only of the order of 15%, whereas in singles yarn this same increase in twist would result in the rubs to break being increased fourfold. Considering the very great difference in the conditions of the two tests as regards the free length of yarn rubbed, it is not surprising that the magnitude of the effect of twist shows such marked variations. Although the effects on the yarn and cloth test results are of the same type they may be due to different causes. The previous discussion of the cloth wear tests indicated that the amount of fibre in the surface was an important factor. In the present case, the higher twist yarns maintain a round surface whilst the lower twist yarns flatten out; on rubbing the former, wear would start on a small area of contact which would gradually increase as the wear of the yarn proceeded, whereas in the latter wear would start on a larger area of contact. In this way the longer wear of the higher twist yarns could be explained, in conformity with the other results.

(2) Weft Twist Varying, Warp Constant

The breaking strength of the cloth in the weft direction shows the definite maximum as in the case when the warp and weft twist were both varied. The strength in the warp direction shows a decrease when the twist of the weft yarn increases above a twist factor of 1·7.

The bursting strength on these samples shows no consistent change with variation of the twist in the weft yarn, and so again demonstrates that the result is dependent entirely on the properties of the warp yarn.

The results of the impact test appear to be erratic to some extent, but they again show a generally higher result with weft specimens, a reversal of the relative warp and weft values from the tensile strength test due to the much lower extension in the warp direction.

The results for the tear strength again show a generally higher value across the weft than across the warp, and the difference appears to show a definite increase with increase of twist in the weft yarn.

The wear test again shows a higher result with warp yarns under tension than with weft yarns under tension, and in both cases the results increase slightly as the weft twist is increased. This again demonstrates that the test result, whether on a warp or weft specimen, depends on the structure of the cloth and on the properties of the yarns in both directions.

DISCUSSION OF RESULTS ON WET CLOTH

A large number of the tests already discussed were repeated on similar specimens from the same materials under identical test conditions, except that the specimens were soaked in cold water for 30 minutes before testing. The results of the tests are summarised in Table IV for the samples with varying closeness of weave, and in Table V for the samples with a constant weave and varying yarn twists. In both cases the results are recorded as a percentage change from the value of the corresponding test on the material in air-dry condition at 75% R.H. As a matter of fact wet tests by each method gave higher results, except in two cases of weft extension, which will be referred to later. Inspection of the tables show that in most cases there is no indication of a systematic variation of the percentage increase in the wet test with the variation in the cloth structure. The only indication of this kind is in the bursting test where the results appear to show a decrease in the percentage increase as the weave becomes closer. The very large variation in the percentage increase in the wet test by any one method on the whole range of samples is also a very striking feature. This appears to be a matter of some importance in relation to the general question of cloth testing, as it

Table VI

Average Per Cent. Increase in Test Results on Wetting Bleached and Twice Laundered Cloth. Plain Weave from 2½ D.S. Line Flax Yarn

Test			Per cent Increase on Wetting		
			Average	Minimum	Max
Tensile strength	.	Warp	19·2	2·8	45·9
	.	Weft	22·1	3·9	43·4
Per cent. extension	...	Warp	30·2	4·5	85·0
	...	Weft	3·1	−20·8	11·3
Breaking strength	..	-	43·4	13·6	86·5
Work to break	..	Warp	23·6	4·0	59·9
	..	Weft	15·8	1·3	38·6
Tear strength	...	Warp	17·1	2·9	48·2
	...	Weft	17·3	5·7	42·0
Rubs to break	...	Warp	134	85	168
	..	Weft	102	87	112

has for some years been an accepted practice to carry out tensile strength tests on some linen fabrics in a wet state as a simple means of overcoming the fact that the strength varies with humidity. This was first suggested by Barr[4] for specification tests on brown aero linen. The validity of the method depends on the assumption that all fabrics made from the same material will show a constant increase in strength when completely wetted out. The present results appear to throw considerable doubt on this point and therefore discredit the reliability of this method of specification testing as a suitable and reliable substitute for the correct method of testing all the samples in condition at a specified humidity. The variations in increase of the wet test would affect both manufacturer and consumer; samples which would fail to

pass a specified dry test might pass a wet test based on the dry test plus an average increase for wetting if they gave an abnormally large increase on wetting and vice versa.

In order to compare the increase in the test result by the various test methods, the whole of the results in Tables IV and V for warp or weft tests by any one method have been averaged, and these figures are summarised in Table VI. So far as we are aware, no such comparison of wet and dry tests by all these various methods has been made previously. It is a matter of definite interest to know whether the relations between samples shown by the various tests on dry samples are maintained in the wet state. It has a direct bearing on the question of any relationship between test results and serviceability of the cloth, as so many linen cloths are stressed in a wet state during use, as for example in the machines during laundering or in wet exposure in the cases of heavy canvases and ducks. The average increases given by the different kinds of test are all positive but vary tremendously. In the tensile and tear strength tests the increases are of the same order and approximately the same in the warp and weft directions. The per cent. extension in the warp direction shows a very large increase, whilst that in the weft direction only shows a small increase. This behaviour is evidently related to the fact that in the dry cloth the weft extensibility was considerably greater than that of the warp. From the relation between extensibility and yarn crimp which has been pointed out, it may be inferred that in the wet cloth the crimp of the warp has been considerably increased, which would occur by warp shrinkage; the crimp in the weft was already very high in the dry cloth and only changed slightly on wetting. The small change in the weft extension would also account for the only two cases in the whole of the observations in which a decrease in the dry test result was obtained; in these cases evidently the error of sampling due to cloth variation has exceeded the small increase obtained on the average on wetting. The bursting test gave an increase in strength approximately double that given by the tensile test. In these bursting tests on wet cloth, it was observed that the bursts were due to breakages of warp and weft yarns, and not warp breaks only as in the dry cloth. This is evidently rendered possible by the greater increase in warp extension, and the high increase in bursting strength is due to the breakage of warp and weft threads. In the impact test, the increase in the warp direction is considerably higher than that in the weft direction. As this again is a test depending on yarn strength and cloth extensibility, it appears that the explanation of the difference in the warp and weft results is again to be found in the very large increase in warp extensibility. The wear test shows a far larger increase than any of the other tests, and from previous conclusions it may be inferred that this would be contributed by several factors such as the increased tensile strength, the increased resistance to wear of the individual yarns, the shrinkage which is equivalent to a closer setting of the yarns, and finally the actual wearing effect of the rubbing surface may be reduced when wet.

All these tests have been introduced as having some relation to specialised aspects of service uses, and in all cases the results with linen fabrics are higher when the material is wet. Tests on these same singles yarn in the wet state gave increases of 14% tensile strength, 26·5% extension, and 30% rubs to break. The increase on wetting is evidently an inherent property in the linen yarn. In the cloth tests, the strength of the yarn enters as a factor, and probably the higher strength of wet linen yarn is a basic factor in the increases

shown by the wet cloth tests. This is confirmed by the fact that the variations in the increases by the different methods are explicable in terms of the relations between the cloth strength and yarn strength as modified by the cloth structure, as deduced in the earlier discussion.

DISCUSSION OF LAUNDRY WEAR TESTS

The results of the repeated laundering tests on the series of weaves from yarns of 1·7 twist factor and on the samples of constant weave from yarns of different twists are summarised in Table VII and shown graphically in Figs. 6 and 7. Results are recorded in each case for the number of complete launderings at which broken yarns were detected (in every case a breakage of warp yarns fairly close to a selvedge) and the corresponding per cent. loss of original weight of cloth. Also in order to indicate the relative rate of loss of weight in laundering, an average per cent. loss in weight relative to the cloth of average weave (sample 41CL) for an equal number of launderings has been estimated. The losses in weight were recorded after 2, 5, 10, 20, 40, 60, etc. launderings; at each of these periods the loss given by sample 41CL was taken as 100, and the losses of the other samples expressed in proportion, and the average of all the figures so obtained for each sample was taken as the average relative per cent. loss in weight for an equal number of washes. This procedure was adopted because the rate of loss of weight is greater during the first few launderings than at a later period.

Table VII
Resistance to Laundry Wear

Ref No	Yarn Twist Factor		Ends per Inch		Times Laundered to First Wear	Per cent. Weight Loss at First Wear	Relative per cent Weight Loss for Equal Washes
	Warp	Weft	Warp	Weft			
29CL	1·7	1·7	23·3	32·8	10	14·5	201·0
30			28·9	32·8	40	19·8	158·8
31			34·0	32·8	60	20·0	124·0
41			39·0	32·1	100	22·9	100·0
32			43·3	32·6	120	28·1	101·3
33			47·2	33·6	140	28·7	94·5
34			49·8	33·7	160	28·6	81·9
35	1·7	1·7	36·1	21·7	40	22·4	188·3
36			37·9	25·3	60	23·4	145·5
37			39·0	29·0	80	25·2	122·8
41			39·0	32·1	100	22·9	100·0
38			39·8	38·2	100	23·3	99·5
39			40·8	41·8	120	23·0	82·9
40			40·3	43·5	140	23·5	80·8
25	1·3	1·3	39·0	35·2	60	14·4	94·4
58	1·5	1·5	38·4	33·2	60	17·2	103·0
41	1·7	1·7	39·0	32·1	100	22·9	100·0
59	1·9	1·9	39·1	33·5	100	20·9	91·6
54	2·1	2·1	39·3	32·5	140	28·8	98·0
60	2·3	2·3	39·8	33·4	100	20·5	90·5
43	1·7	1·5	39·3	32·3	100	24·3	113·1
41		1·7	39·0	32·1	100	22·9	100·0
42		2·1	38·6	32·5	100	23·0	106·1
44		2·3	39·7	32·4	100	23·0	106·2

The results shown in Fig. 6 for the varying weaves show several interesting features. The number of washes to give the first signs of wear increase uniformly with increase of the number of warp or weft ends per inch. The number of launderings withstood without wear increases at a greater rate with increasing closeness of warp yarns than with increasing closeness of weft. In the more open weaves, the fabric with 22 weft ends per inch shows wear at

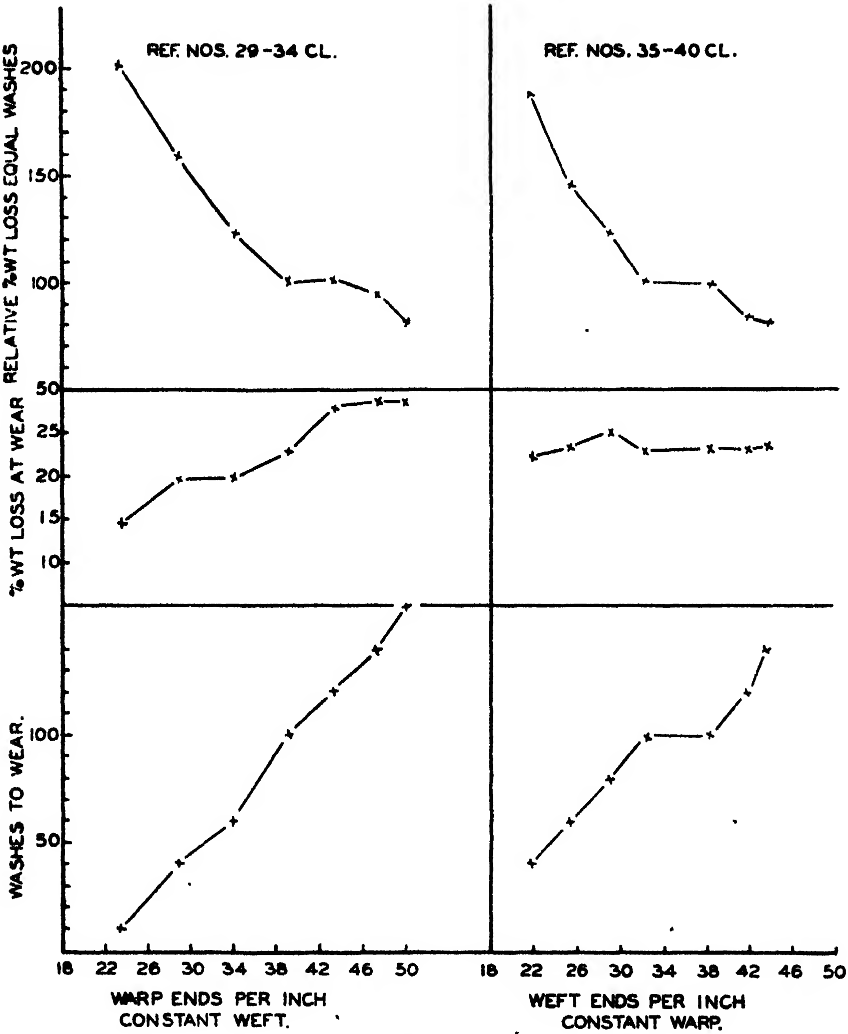

Fig. 6

40 washes as against 10 washes for the fabric with 23 warp ends per inch. This of course may be due to the constant warp ends in the former case (39 per inch) being greater than the constant weft ends in the latter case (33 per inch). If, however, the two sets are compared on an equivalent basis of weight per square yard or compactness, it will be found that under equal conditions the set with increasing weft ends per inch show greater resistance to laundry wear at low values (open weave) and less resistance at high values (close weave). This appears to show that although the resistance to laundry

wear in these towel lengths depends on the closeness of weave in both directions, yet the closeness of setting of the warp yarns has a greater effect than the closeness of the weft yarns.

The second set of curves show the per cent. loss in the original cloth weight after the number of launderings at which the first signs appear. A distinct difference is shown between the cloths with increasing warp and increasing weft ends per inch. In the former, the cloths can lose an increasing percentage of their original weight before wear appears, but with the latter the

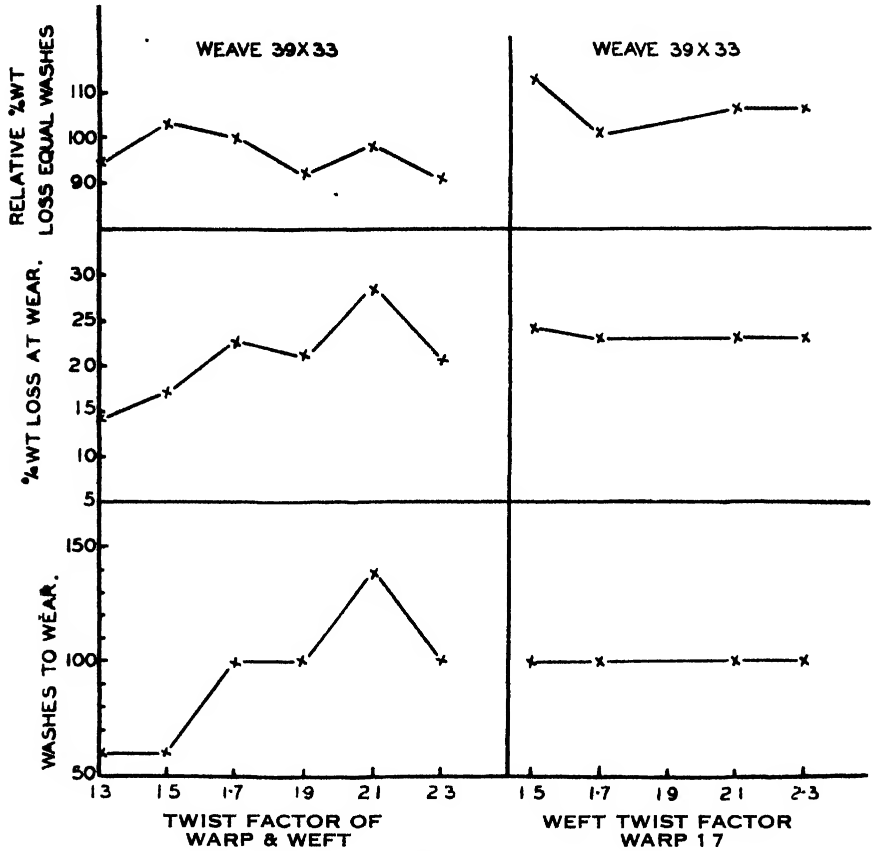

FIG. 7

signs of wear appear when the cloths have lost a certain percentage of their original weight. This is a very significant result and would appear to confirm the previous indication that the warp setting is the more important, since with constant warp setting the weight loss at wear is constant, and with increasing closeness of warp setting the weight loss at wear increases approximately in proportion. Taken together with the fact that the first wear always appears as breakage of warp yarns, the results appear to demonstrate fairly conclusively that the important factor determining the number of washes the cloth will stand is the number of warp threads per inch.

The top curves in Fig. 6 indicate the rate of loss of weight by the various weaves for an equal number of launderings, relative to that of medium closeness. The curves are generally of the same shape, showing a rapid increase

of weight loss per wash with an opening up of the weave, and a much slower decrease in weight loss on closing up of the weave. It can just be distinguished that the increased rate of loss of weight with decrease of ends per inch is smaller with change of number of warp ends than with change of weft ends, which is in agreement with the earlier remarks on the curves showing the number of launderings to produce wear, and confirms that appearance of wear and weight loss are inter-related.

Fig. 7 shows corresponding curves for a constant weave from varying yarn twists. When the warp and weft twist are varied simultaneously the number of launderings to show first signs of wear increases to a maximum for a twist factor of 2·1. The per cent. loss in weight when wear appears follows a similar curve, the cloth being able to lose an increasing percentage of its weight with increased yarn twist, up to a twist factor of 2·1. In a general way the weight loss for an equal number of washes decreases with increase in yarn twist.

When the weft twist only is varied on a constant warp, the number of launderings to show the first signs of wear is constant, except for a visual observation that at this number of launderings the extent of the wear which occurs is slightly more pronounced with the wefts of lower twist. The weight loss from these fabrics when wear occurs is constant as also is the relative weight loss for a given number of launderings. It is clear that the results only show variations when the twist of the warp yarn is varied, which appears to confirm the previous conclusions in a very striking manner, and adds the further conclusion that in addition to the closeness of the warp settings, the properties of the warp yarns are of greater importance than the corresponding factors relating to the weft yarn.

DISCUSSION OF TENSILE STRENGTH TEST

The results of the tensile strength tests on fabrics containing structural variations have been discussed and indirectly several inferences were drawn as to the effects of the cloth structure on the results. Further information as to the possible interpretation of tensile test results on fabrics may be obtained by considering the results not as breaking load on a strip of constant width, as has been done, but as the breaking load per single end. For this purpose the results of the tensile tests recorded in Table II have been recalculated in this way and they are shown graphically in Fig. 8 for the warp and weft yarns of the six sets of fabrics, increasing closeness of weave, warp or weft, each from three twists of yarn. The curves now assume shapes very different from those showing the breaking load on the 2-in. strip. Whilst certain points show fairly wide divergencies, on the whole the general trends are obvious and in fairly good agreement in the three curves in each set. Since the same yarns are used throughout as warp and weft, the curves referring to yarn of the same twist factor should if continued back to the ordinate at one end per inch all cut it at the same value, the strength of a single end tested between the jaws of the machine; this is indicated in the figure by the dotted line. In the top three sets of curves, it is clear that the results for cloth strength per single thread show a continuous increase with increased closeness of weave, and the rate of increase is greater in the two weft tests than in the warp test with constant warp. A very different behaviour is shown in the bottom set of curves for warp tests on fabrics with constant weft; as the number of warp ends is increased the cloth strength per

single end increases to a maximum and is followed by a decrease to a minimum, when the strength again increases. The possibility of the effect being due to chance or errors due to cloth variation or sampling appears to be definitely discounted in view of the close similarity in the results from three independent sets of fabrics. So far as the writer is aware, there is no previous record of this effect. It is evidently an outstanding feature of the results and

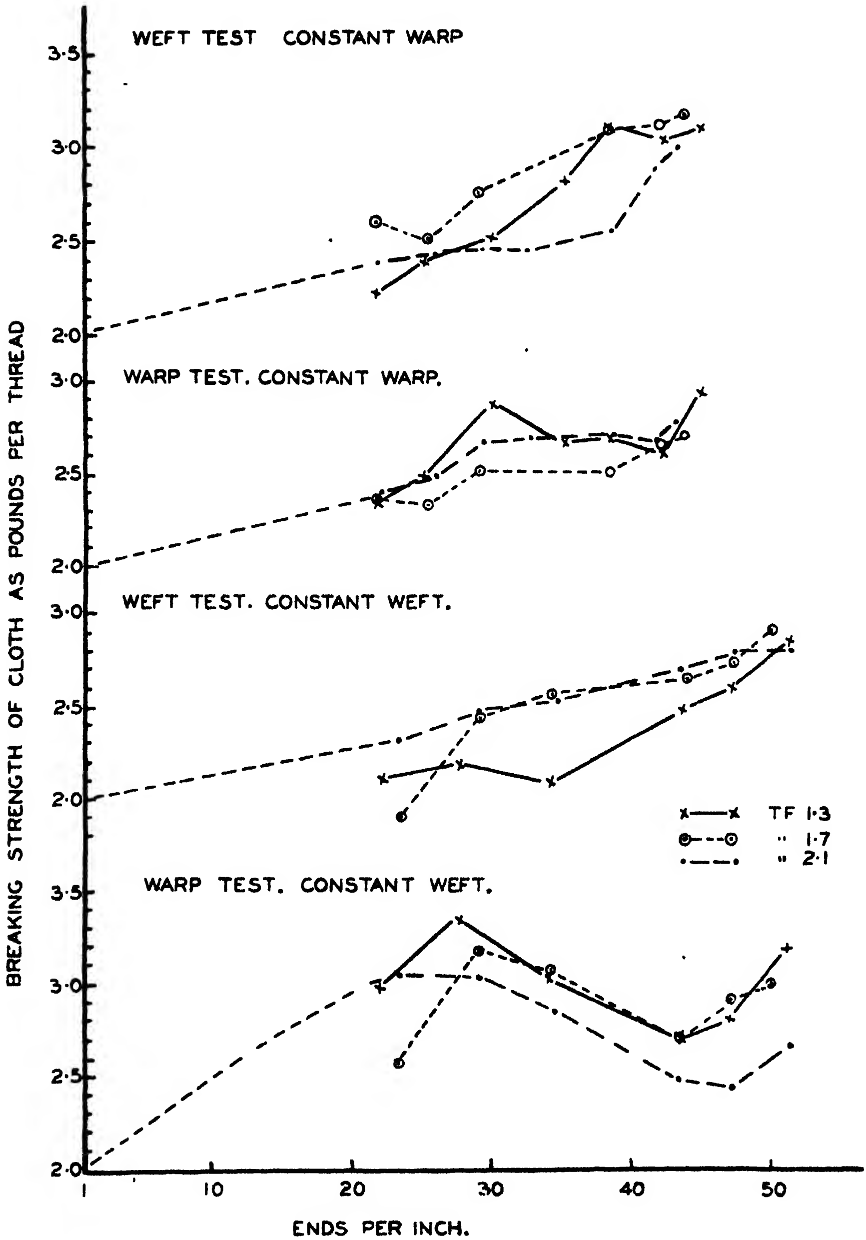

FIG. 8

therefore it may be presumed that it could be used as a most conclusive check on any proposed theories as to the interpretation of the meaning of tensile test results in terms of cloth structure and yarn strength.

This question has been discussed at some length in a general theoretical manner by Turner[5] by considering the stress distribution in the test specimen when on the point of breakage.

It is stated that the friction between the yarns at the intersections normally prevents any slippage at these places, as the behaviour of the specimen depends on the bending or corrugations, which make the length of yarn greater than the length of cloth according to the yarn count, type, and closeness of weave (number of intersections) and the relative compressibilities, and also introduce a strengthening effect by making the free spans of yarn very short. He explains the waist or narrowing at the centre of a specimen under load as due to a deepening of the corrugations in the transverse threads caused by the tension producing straightening of the longitudinal threads. The transverse threads therefore contract laterally dragging the longitudinal threads inwards. This occurs to a maximum midway between the jaws; at the jaws the longitudinal threads are held out to width, and so near the jaws there is a resistance to inward movement by the cross threads, causing a tension in the cross threads, greatest at the middle and decreasing to zero at the edge of the specimen. As this tension decreases the possible deepening of the yarn corrugations increases, so near the jaw the transverse threads will be more corrugated at the ends than in the centre. On the other hand, longitudinal threads at the side will have their corrugations removed by the tension, but in the middle will retain them to a greater extent. Passing away from the jaw the effect diminishes till midway between the jaws, the transverse threads will be deeply corrugated and the longitudinal threads straight. It is then supposed that at first the extension of the cloth is due to removal of corrugations when further extension is more largely due to extension of the yarns alone. At the stage in the loading when removal of corrugations is fairly complete, according to the above discussion, there will be a longer length of straight yarn at the edges of the specimen than in the middle, so that outside longitudinal threads can extend more than central threads before break occurs. Therefore under any load on the specimen the straight parts of the central threads will be nearer their breaking extension than the outside threads and so must be under a higher stress. There will be a gradual decrease in stress from the centre outwards, and if all threads are quite uniform, the specimen should break at the central thread first. Obviously the extent of the inequality in stress across the piece would depend on the relative corrugations in the two sets of threads, and generally if longitudinal corrugations are deeper than the transverse corrugations the stress inequality will be greater than when the transverse corrugations are deeper than the longitudinal corrugations. The primary failure of the central thread in this ideal cloth from uniform yarn would throw additional stress on neighbouring threads and so on at this point, so the break would rapidly extend across the specimen from the centre and therefore the failure of the cloth would be in the nature of a tearing (wound) strength test, and final rupture more of a tear than a break. In actual cloth it is possible that the inequality of stress effect may be offset by the irregularity of the yarn. The weakest or least extensible parts of the irregular longitudinal threads will be distributed along the length of the specimen, and so the first thread breakage may occur at various places.

The actual breakage of any one will throw additional stress on adjacent threads. The primary break to extend will be the one at which there is concurrence of adjacent weak threads. Several such spots may occur when rupture would be expected to occur in more than one place and in fact such breaks are very common. If the weakest part of the irregular yarn occurs in the centre of the central thread, the effect of stress inequality will be increased, but if it occurs in an outside thread, it will tend to counteract the effect of stress inequality. Turner proceeds to consider the effect of size of specimen on the strength. The total stress in the transverse thread at any point is taken as equal to the sum of the stresses due to all the longitudinal threads intersecting from the side to the point in question. At the side the tension in the transverse thread is zero, and on passing inwards increases in proportion to the number of intersections which is proportional to the width of the specimen. He states that this greater stress in the centre of transverse threads in wider cloth specimens would lead to smaller removal of corrugations in centre longitudinal threads by external load on wide than on narrower specimens. This would give increased stress inequality with increase in width and so the central longitudinal threads would be strained to breaking point under lower external load in the case of wide specimens. Very narrow specimens, he concludes, may be relatively less strong because of loss of addition to strength due to intersections (not previously mentioned), and so on the whole he expects the strength to be at a maximum for a certain width of specimen. The effect of length is considered and it is stated that as the length increases the jaw effect decreases in importance, so unevenness of stress distribution is less, and therefore the strength of the specimen should increase with length. On the other hand the effect of yarn irregularity is in the opposite sense. Further discussion is given to the case of fabrics made from heavy and light yarns and the effect of humidity and wetting. This need not be gone into, since the arguments are based on the previous conclusions.

Now up to a point this exposition of the effects on the individual yarns in a cloth test specimen is in a general way quite straightforward. When, however, it comes to a question of applying the theory to definite cases such as the effect of size of specimen, then the result depends on the assignment of relative values to the effects of stress inequality across the width midway between the jaws, the inequality of stresses close to the jaw, and the effects of yarn irregularity. Actually nothing definite is known about the relative magnitudes of the effects. Turner, however, makes various suppositions and draws several conclusions which are explicitly stated. He concludes (1) that the strength of the specimen will be at a maximum for a certain width, (2) the strength should increase with length of specimen, (3) on wetting, the strength of low twist yarn should increase much more than high twist yarn, (4) the tensile test gives a false idea of the strength of the warp (making it appear weak), but gives no false idea of the strength of the weft. No statement was made as to how these theoretical conclusions compared with actual experimental results, although they are all capable of being checked directly. In order to check the validity of these conclusions some additional measurements were made on some of the fabrics used in this work. The effect of width of test specimen was tested in some warp tests on two structures. In the first sample the warp ends were set far apart and the crimp or corrugation in the warp yarn was small, and in the second sample the warp ends were set close

together and the warp crimp was large. The results of warp tensile strength tests are summarised in Table VIII, showing the breaking load on the strip

Table VIII

Warp Tests on Goodbrand Machine (Dry). Strips 7 inches between Jaws

Sample Ref No	Ends per Inch		Width of Strip Inches	Actual Average Ends per Strip	Breaking Load	
	Warp	Weft			Pounds on Strip	Pounds on Single End
29CL ...	23·3	32·8	1	23·3	57·2	2·45
			1½	34·6	88·0	2·54
			2	46·5	118·7	2·55
			2½	57·3	144·2	2·52
			3	68·8	176·2	2·56
			3½	82·8	189·8	2·29
34CL ...	49·8	33·7	1	50·8	139·8	2·75
			1½	77·2	211·5	2·74
			2	102·8	267·2	2·60
			2½	129·2	330·0	2·56
			3	154·2	388·8	2·52
			3½	177·2	478·8	2·69

Table IX

Sample Ref No	Ends per Inch		Cloth Test Breaking Load Pounds per Single End		Yarn Test Breaking Load Pounds	
	Warp	Weft	Warp	Weft	Warp	Weft
29CL ...	23·3	32·8	2·57	1·91	2·54	2·08
30 ...	28·9	32·8	3·18		2·63	
31 ...	34·0	32·8	3·07		3·00	
32 ...	43·3	32·6	2·69		2·88	
33 ...	47·2	33·6	2·91		2·79	
34 ...	49·8	33·7	3·00	2·91	2·77	3·09
35 ...	36·1	21·7	2·35	2·61	2·46	2·63
40 ...	40·3	43·5	2·70	3·17	2·87	2·83

Ratio $\frac{\text{Close}}{\text{Open}}$ Weave Strength

Sample	Warp		Weft	
	Cloth Test	Yarn Test	Cloth Test	Yarn Test
Cloth, constant weft 29CL ...	1·16	1·09	1·52	1·48
Cloth, constant warp 35CL ...	1·15	1·16	1·21	1·07

and the breaking load calculated on a single end. It will be seen that the strength per single thread is fairly constant for strips varying from 1–3½ in. in width. Barr,[6] working with several types of fabric, concluded that there was no definite maximum or minimum relation between the strength and dimensions of the test specimen, either in length or width. He found the effect of width was variable and usually small. In Table IX the results of some fabric strength tests, calculated per single end, are compared with the results of single end tests on yarns frayed out from the same cloth. In the

latter 100 breaks were made with specimens 7 in. between the jaws of a Smith yarn tester; rate of loading, 120 oz. per minute. The actual values are not directly comparable, owing to differences in rate of loading conditions, but there should be some significance in the relative values from the two tests for the warp or weft from the different cloths. Actually the values are of the same order, and there is on the whole general agreement as to the nature of the change in warp and weft strength with change in weave. There is therefore no evidence here that the tensile test gives any more unreliable idea of the strength of the warp than it does of the weft yarn. It was previously shown that the increase in strength on wetting showed no consistent change with closeness of weave or of yarn twist. The experimental data from these linen fabrics are therefore entirely contradictory to the theoretical conclusions of Turner.

This suggests some error in assignment of relative importance to the different effects; the method of consideration of the problem in terms of the corrugations at various parts of the specimen is most helpful in allowing the formation of mental pictures of the effects and explaining the superficial effects of formation of waist and the type of breaks. Retaining this part of the discussion, an alternative explanation of the size of specimen effect may be suggested more in keeping with the experimental results. Turner's explanation of both length and width effects hinges on consideration of the magnitude of the jaw effects (this is stated definitely in the length effect and is to be inferred from the argument as regards the effect of increased stress on the transverse threads on the extent of removal of corrugation from the longitudinal threads), and on the magnitude of the stress inequality set up across the width. These he evidently regards as having very considerable effects on the breaking load of the specimen, and particularly the latter, since he even considers the breaking load in certain cases as approximating to a tearing (wound) strength. It is suggested that closer agreement with experiment would be obtained by considering these effects as of very much less importance. If the jaw effect be supposed to extend only a short distance from the jaw, it could be neglected in test specimens of ordinary length. If further it is assumed that the behaviour of the test specimen is in general controlled by that of the yarns in the mid-region between the jaws, the problem is simplified, because at the breaking point the longitudinal yarns may all be regarded as straight and the transverse yarns as all very much corrugated. The practical independence of strength and test length would follow naturally. The magnitude of the stress inequality across the width due to the differential length of centre and side longitudinal threads from which corrugations are removed by the external load, would be minimised on the same grounds, and as this is also offset by the curvature of the side threads and the effects of yarn irregularity, it may finally be supposed that the effect on the breaking load may not be so very pronounced. The proportionality between breaking load and width of specimen would then necessitate the assumption that the effect of curvature of the outside threads compensates any tendency for the jaw effect to extend away from the jaw in wider specimens.

Confirmation of this view is obtained from further consideration of the results in Table IX and comparison with those shown in Fig. 8. The strength tests on single yarns frayed from the fabric show considerable variation with the weave, all showing a marked increase when taken from the close weave. Further in the series of samples with constant weft, increasing warp ends, the

single yarn tests on the warp yarns show a definite increase to a maximum, which appears to be very significant in view of the fluctuations for the cloth strength per single end given by these same samples. These results would appear to indicate that the variations in cloth strength per single end as shown in Fig. 8 are very largely due to changes in the actual strength of the yarns in the samples with varying closeness of weave. The variations in strength are present in the yarn itself after removal from the cloth and are not merely temporary increases on the cloth strength due to binding effects caused by the presence of transverse threads in the cloth whilst it is being tested. This is important as it leads to the conclusion that the tensile strength of the cloth is a very fair index of the strength of the yarn as it exists in the cloth and also that the variations in the yarn strength with weave are due to variation in the effects of the imposed pressure or stresses applied in the previous finishing process. Consideration of the internal structure of the samples as indicated by the curves for outcome in Fig. 1 suggests that the yarn strength changes as indicated in Fig. 8 are largely explicable if it is assumed that the yarn is strengthened by the compression at each intersection, and that the extent of compression and therefore the strengthening is greater the greater the corrugation of one or other set of yarns; it must also be supposed that the greater compression is taken by the more corrugated set, but the transverse set of yarn also receives some compression. Thus in the top set of curves the weft yarn is tensioned and in the series of samples the warp ends per inch are constant, so the number of compressed parts at intersections in the length of the test specimen is constant, but the weft corrugation increases throughout the series, indicating an increased compression effect on the yarn strength. In the second set from the top, warp tests in which the number of weft threads increases throughout the series, the warp corrugation remains constant, but the number of weft intersections or compressed parts in the test length will increase progressively and so account for the regular increase in strength. Similarly in the third set the increase in strength would be accounted for mainly by the increasing number of compressed parts at intersections by the increasing number of warp ends. In the bottom set the number of intersections by the weft in the warp test length would be constant, but in this case the warp and weft corrugations both vary throughout the series. The weft corrugation increases to a maximum, the warp corrugation remaining constant, and in line with the above remarks, an increase in warp strength would be expected as shown. The weft corrugation then decreases whilst the warp corrugation increases and according to the tests of Table IX the yarn strength decreases. This is not quite in agreement with the curves of Fig. 8 as these show a second increase in strength, which may be a real binding effect increasing the strength of the yarn whilst held *in situ* in the cloth.

The discussion of these cloth test results in the early part of this paper is on conventional lines. It must be realised, however, that two assumptions underlie that discussion, (1) that the presence of transverse threads in the specimen exert an effect on the apparent strength of the longitudinal threads, and (2) that the single thread test strength of the yarns in the fabrics of varied weave remains constant. It was therefore concluded that the increase of cloth strength shown by the specimens with a constant number of longitudinal threads and increasing transverse threads was entirely due to this binding effect. The results of Table IX show that the second assumption is not correct, but do not prove that a binding effect in the test specimen is

absent, since the cloth and yarn tests are not directly comparable in actual values. Some investigation of this point may be made, however, from these results by comparing the ratio of single end strengths from cloth and yarn tests for two weaves. This is shown in the lower part of Table IX for the closest and most open weaves in the two series. This ratio should be the same for cloth and yarn tests in the absence of a definite binding effect in the test specimen. The ratio is higher in the cloth tests on specimens with increasing number of ends, but not in the specimens with increasing closeness of the transverse ends. In the former cases this would apparently indicate an increase in strength in the cloth test with increasing closeness of weave which is not shown by the tests on single ends frayed from the cloth. The presence of an actual binding effect may therefore be inferred in these cases, but no binding effect when only the closeness of transverse ends is varied, such as was assumed to explain the results in the earlier discussion.

The general conclusion from this discussion therefore would be that the tensile strength of a cloth specimen is very largely the sum of the strength of the single ends, as modified by the compressions at the intersections during finishing, plus some smaller effect in certain cases due to the presence of transverse threads whilst being tensioned in the testing machine. The effects of irregular stress distributions in the test specimen appear to be localised near the jaws and have but small effect on the breaking load. The yarn corrugations affect the cloth strength inasmuch as they cause variations in the strength of the yarn under the compression exerted in finishing, but not from unequal stress distribution resulting from the extension, which, as is shown in the next section, is directly controlled by these corrugations.

EXTENSIBILITY OF CLOTH

It has already been observed that there appeared to be some close relation between the curves for extension at break and the crimp in the longitudinal yarns in the test specimens. In order to consider this in more detail, the results for extension from Table II are plotted against the per cent. outcome of the lengthways yarn in Fig. 9 for four sets of fabric from yarns of two twists. The lower half of the figure contains the results from specimens in which the closeness of the transverse yarns was constant whilst the closeness of the longitudinal threads was increased. There is a slight but definite separation between the sets containing the different twist yarns; for the same per cent. outcome, the specimens containing the higher twist yarn giving the greater per cent. extension at break. The main feature, however, is the very definite linear relation between per cent. extension and per cent. outcome in these particular samples.

The upper half of the figure contains the results from specimens in which the closeness of the longitudinal threads was constant whilst the closeness of the transverse threads was increased. The results for the four sets appear as four distinct groups. There is a large difference between the average per cent. extension and per cent. outcome for each group, and from this point of view there is again shown the general relation between extension and outcome. In these samples there is a much more marked difference in extension between the groups from different twist yarns than in the previous. In two groups, where the increasing transverse ends are warp threads, the weft outcome varies over a good range and a slight increase of extension with increased outcome is noted.

Both sets of results are therefore in accordance with the general conclusion that the extension of the cloth at break is directly proportional to the crimp or per cent. outcome in the yarn in the direction of tension in the specimen Added to this is the contribution from the extension of the yarn itself, the value of which is obtained by projection of the curves to cut the zero outcome ordinate.

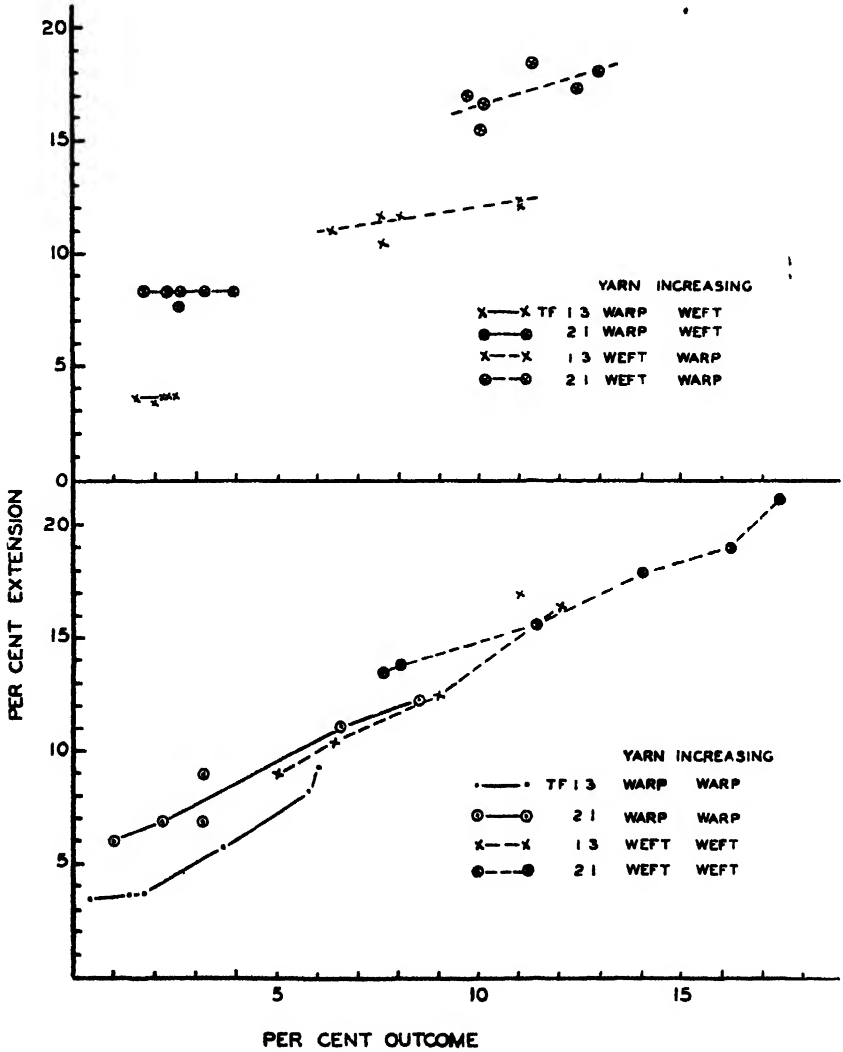

FIG. 9

COMPARISON OF LABORATORY AND LAUNDRY TESTS

Regarding the repeated laundering of a cloth as a way of testing the resistance to wear of cloth under one sort of practical conditions, it is then a matter of interest to compare the results obtained with those given by the laboratory tests in which the behaviour of the fabrics are determined under the standardised test conditions. The method of repeated laundering is of course quite impractical as an ordinary test method owing to the very

considerable time involved in obtaining a result. It would, however, be of considerable importance to know whether any laboratory test can give results which would place samples in the same relative order. If any such relation exists for the laboratory tests employed in this work, then the test results plotted against closeness of weave or yarn twist in Figs. 2–5 should give curves similar in shape to those for the washes to wear in Figs. 6 and 7.

It is at once obvious that the bursting strength and the tearing strength tests can be eliminated; the extension is not a measure of durability unless the change in size assists the destruction in some way, and in any case the curves are not of the desired kind. The remaining three laboratory tests present a difficulty inasmuch as they give separate results for the cloth in the warp and weft directions and these vary in different ways with variation in weave, except in the case of the rubbing test, which is one point in its favour. In addition to this the curves for rubs to break against weave or yarn twist on the whole are very similar to those for washes to wear in all the four sets available for comparison, and the similarity is most marked in the case of warp specimens.

Since it is an observed fact that normal wear in laundering is always first indicated by warp breakages, irrespective of the direction in which the cloth is put through the finishing machines, it might be considered justifiable to give more weight to warp laboratory tests. If this is done in the case of the impact test, similarity is fairly good for the effect of yarn twist and increasing number of warp ends, only a slight increase is shown, however, on increasing number of weft ends, due to the constancy of the per cent. extension. In the case of the tensile strength test, the curves for warp tests are generally very similar to those for washes to wear, except that the strength shows a decrease with increasing weft twist not shown by the laundry tests.

So far then it would appear that either the tensile strength or the resistance to wear by rubbing tests of warp specimens would give results on these various fabrics which would place them in the same relative order as the repeated laundering test. The relation of laundering test to tensile strength might appear reasonable on the grounds that wear shows first as warp breaks, and it has been concluded that the tensile strength of cloth indicates very faithfully the yarn strength. If this argument is pursued, however, it would lead to the suggestion, since the first wear is localised on one or two warp threads, that the resistance to laundry wear should be proportional to the strength of single ends of the warp. This is not borne out, since the single yarn strength of the warps in the fabrics with increasing warp ends was actually found to rise to a maximum, and so comparison with the laundry results would fail. Again in these same fabrics the single yarn tests show the warp yarn is rather stronger than the weft, which is not in accordance with the fact that the warp gives way first. It seems clear therefore that resistance to laundry wear is not directly related to tensile strength of the single ends. The apparent relation between washes to wear and tensile strength of the specimen may therefore be a coincidence, and certainly requires confirmation on other types of cloth before it could be accepted with confidence.

The apparent relation between the washes to wear and rubs to break if true would suggest that the wear in laundering is mainly due to a frictional effect. The results of investigations on laundry wear are not opposed to this conclusion since it is known definitely that the greater part of the wear occurs in the washing machine itself where the goods are in a revolving cage and are repeatedly dragged out of the liquor, lifted, and dropped back, so that

rubbing between cloth and cloth or cloth and metal would occur, and the cloth may be tensioned owing to entanglement. Further comparison on other cloths is again desirable to establish definitely this apparent relation, but from the present results the rubbing test appears to give a closer estimation of the relative resistance to laundry wear than any of the other laboratory tests employed.

SUMMARY

The changes in internal and external characteristics of twice laundered plain linen cloth on varying the closeness of weave in either the warp or weft directions are considered. The effects vary according to the character considered and may be very different with variation of closeness of weave in the two directions.

The results obtained on specimens of these cloths from tests of tensile strength, extension at break, work to break, tear strength, and rubs to break are discussed. Also similar tests on cloths of a constant weave with variations in the yarn twist are discussed. Most of the tests were repeated on specimens soaked in cold water and the results are recorded as the percentage change on those of the dry tests. Results are also given of tests on certain series of cloths repeatedly laundered till wear appeared. The relation of yarn strength and cloth tensile strength is considered by comparison of tests on single yarn frayed from the cloths, with the results of the cloth tests expressed as pounds per single end. The views of Turner are considered and compared with the above data. The results recorded are discussed in relation to the effects of variation in closeness of weave or changes in yarn twist, and also as to the relation with structural characteristics resulting from these changes. Finally the results are discussed from the point of view of comparing the results of the laboratory tests with those from the practical wear test by repeated laundering.

The results from the different test methods show varying effects according to the way in which the structure is varied. These are generally explicable when regard is paid to the resulting changes in internal structure and to changes in cloth behaviour caused thereby. From the data it can be concluded that certain test methods give results depending on the cloth structure irrespective of directional variations, others depend only on the properties of the single yarns, whilst others depend on more than one property of the cloth. The main conclusions drawn from the whole of these various considerations of these test data on twice laundered linen cloth of plain weave may be summarised as follows—

(1) *Tensile Strength* of cloth depends on the closeness of weave and on yarn twist. The strength in both warp and weft directions alter on varying the structure in one direction only and the breaking load is proportional to the width of the specimen. In a series of cloths made from the same yarn, the cloth strength varies; these variations are due primarily and are very approximately proportional to changes in the strength of the single ends of yarn in the fabric brought about by the compression effects at intersections during finishing. In some cases an addition to the cloth strength is caused by the presence of transverse threads in the cloth whilst under tension in the testing machine. The extent of the relative changes in yarn strength by the compressions depends on the closeness of the intersections in the cloth and the amount of corrugation.

(2) *The Extension at Break* is equal to the yarn extension plus an amount proportional to the corrugation or per cent. outcome of the yarn in the longitudinal direction of the test specimen.

(3) *The Bursting Strength* as determined on the Mullen machine gives results which are generally relatively similar to the tensile strength results in the less extensible direction, in cloths in which the extensibility is very different warp and weft way. The test is only applicable therefore as a repetition test for comparison of the same structure.

(4) *The Work to Break or Impact Strength* of cloth depends on the closeness of weave and yarn twist, because of the effects of these structural changes on the strength and extension of the cloth. The work to break is more independent of the number of transverse threads in the specimen than in the tensile strength test. It appears that perhaps the impact test measures the yarn quality in the cloth more definitely than the tensile test, but only in cloths of approximately the same extensibility. In samples from yarns of approximately equal strength, the work to break becomes merely an indication of cloth extensibility.

(5) *The Tearing Strength* depends only on the properties of the yarn in the fabric as it shows very little change with closeness of weave but a slight increase with increase of twist. On the whole the tearing strength across the weft was rather higher than that across the warp in these samples. It is concluded that this is due to greater compression in the weft yarn rather than to greater extensibility of the cloth in the weft direction.

(6) *The Resistance to Wear by Rubbing* increases with increasing closeness of weave and with increase of yarn twist, whether the warp or weft yarns are under tension during the rubbing. It depends on the state of the cloth as to whether the result is higher in the warp or weft specimens. With either sort of specimens the result depends on the structure of the cloth as a whole.

(7) *The Resistance to Laundry Wear* depends on the closeness of weave and on yarn twist. Wear always shows first as breakage of warp threads near the selvedges. The properties and the closeness of the setting of the warp yarns appear to be more important than those of the weft. The number of washes to cause wear appears to be related to the rate of loss of weight, whilst the loss in weight which can take place before wear shows appears to be related to the closeness of setting of the warp yarns.

(8) The tests on *Wet Linen Cloth* all show an increase, which does not vary consistently with the cloth structure. The percentage increases on wetting by any one method of test are very variable, which appears to cast some doubt on the soundness of carrying out specification tests on wet material in order to overcome the difficulty of the effect of humidity on test results. In these cloths there was a large difference in the warp and weft increases of extension on wetting and this has an effect on tests affected by extensibility, and so the increases on wetting given by different test methods are found to vary very considerably.

(9) It is concluded that the tensile strength and the resistance to wear by rubbing tests on warp specimens of cloth give results which for all these samples are in the same relative order as the results for washes to wear in actual repeated laundering trials. None of the other laboratory tests used in this work show any consistent comparison. The similarity in results is perhaps rather closer with the rubs to break, but this requires confirmation with other types of cloth.

It is evident that there is no one test alone which determines the probable serviceability of a cloth under all conditions, but it would appear that measurements of tensile strength, warp and weft, per cent. extension at break and resistance to wear by rubbing are capable of supplying all the essential facts about a given cloth. Probably in certain cases wear may most likely occur as a rip or tear, but the tear strength depends on the single yarn employed, and for specification purposes the use of a specified quality of yarn can be covered by the tensile test. Other tests such as bursting or impact depend on strength and extensibility in some way, and again it appears more definite to measure these separately. None of the tests measure the actual strength of yarn used in making the cloth; at the best the yarn strength may be measured approximately as it exists in the cloth after modifications occasioned by bleaching and finishing treatments. The specification test can only ensure constancy of the combined strength. This, however, should be a definite guide to serviceability since the original specification would be based on the known behaviour of cloth of this kind, provided the structure is identical as shown by the weight per sq. yd., counts of ends and extension of cloth.

The testing work involved was largely carried out by Mr. R. Kirkwood.

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TRANSACTIONS

39—A COMPARISON OF THE FINENESSES OF BRITISH AND CONTINENTAL STANDARDS FOR COMBED TOPS

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In relating the term wool quality to the various attributes of the wool fibre there can be little doubt that the property of fineness is the most important single factor. Other characteristics such as length, crimp, elasticity, and lustre are of decided importance in assessing the manufacturing values of a sample of wool, yet it is only in so far as these properties are present to an abnormal degree that an evaluation of quality based on fineness alone is called into question.

This view is supported by the results of a series of measurements recently published from this laboratory. These results show that for a range of selected British tops there was an increase in fineness according to a definite law as the scale of qualities ascended from 48's to 80's quality. The measures of fineness used to establish this relationship were (*a*) the mean cross-sectional area and (*b*) the weight per unit length of fibre.

In all subsequent work it was decided, in accordance with the resolution of the International Wool Conference of 1929, to adopt the system (*b*) and to express fineness in terms of the weight in milligrammes of 10 metres of fibres at a regain of 18¼ per cent.

According to this system of expressing fineness, the relationship found between quality appellation and the mean fineness for the British selected tops may be represented by the equation—

$$\log_{10} \frac{W}{L} = 0{\cdot}068x + 0{\cdot}44,$$

where $\frac{W}{L}$ signifies the weight in milligrammes of 10 metres of fibre at 18¼% regain and the successive values of x.........3, 4, 5, etc. stand for the qualities 80's, 70's, 64's, etc The psycho-physical implications of this logarithmic relationship are discussed in the previous paper, where it is shown that the Fechner-Weber law, as applied to the visual sense, would account for this manner of variation of fineness from quality to quality. Below the 48's quality on the British scale the law no longer holds. The presence of medullated fibres makes the weight/length method of fineness measurements unreliable over the lower end of the scale, but even when we take the values for cross-sectional area it is difficult to reconcile these with the law governing the finenesses of the higher qualities. It may be that in the estimation of these qualities criteria other than the mean finenesses of the wool have entered.

In the previous paper it was also shown that, when such measurements as were available for the mean finenesses of the French, German, and Italian

standards for combed tops were examined, a similar relationship was found to obtain in every case; the logarithm of the fineness plotted against the successive qualities yielded a straight line. This was interesting since it implied that the fundamental basis underlying wool sorting was the same in all countries. It must be remembered, of course, that in general Continental machinery is adapted to deal with wools which are shorter for their fineness than the types favoured by British manufacturers. Nevertheless it appears that the various qualities differ in point of fineness in exactly the same manner as the English combed tops except that a different number of grades may be employed.

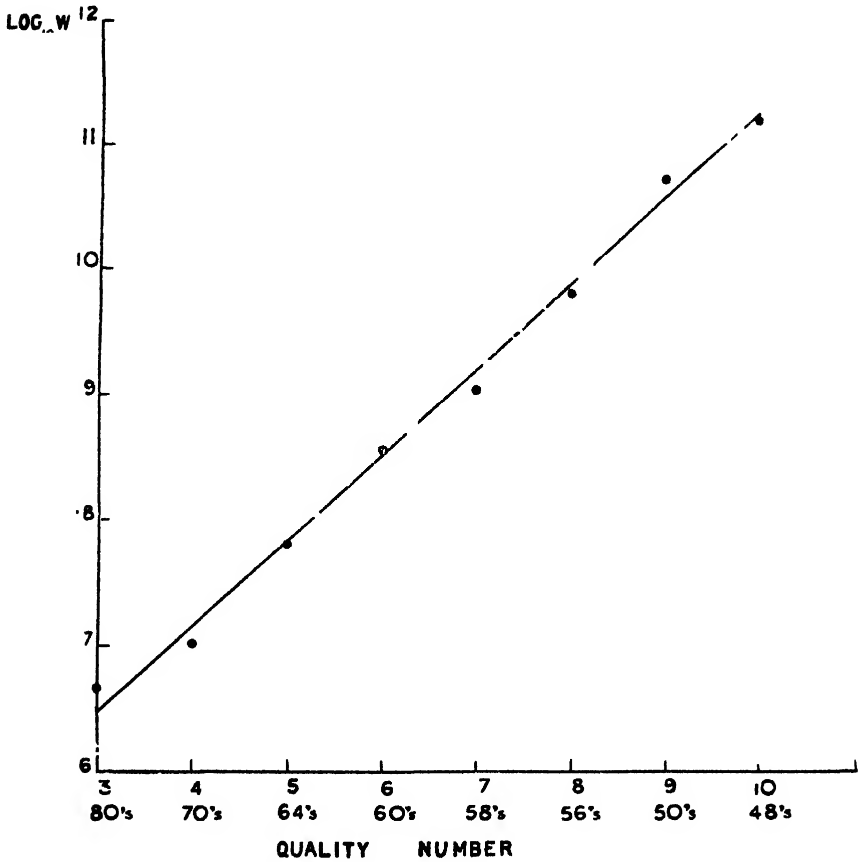

FIG. 1. British Selected Combed Tops.

The measurements of fineness which were used to establish the relationship outlined above were obtained from the literature of the countries in question. Naturally they were not all measured on the same system. The British and French figures applied to measurements made on the weight/length scale, while the German and Italian figures were obtained from microscopic measurements of fibre width. Even when the principle of the method was the same the technique differed and it was therefore difficult to make direct comparisons. The fact that the property of fineness varied in the same perfectly

definite manner from quality to quality makes it possible to use this property to compare qualities on the different national scales.

With this end in view a set of standard combed tops has been obtained from each of the countries France, Belgium, Germany, and Italy. These have been examined by the technique previously employed for the British selected tops and it is thus now possible to make direct comparisons between the different national standards.

EXPERIMENTAL

The method employed consisted essentially in weighing a counted number of fibres cut to a definite length. The work may be conveniently divided into the following stages—

(1) Sampling of top.
(2) Parallelisation and cutting of fibres.
(3) Counting of fibres.
(4) Washing, drying, and weighing of fibres.

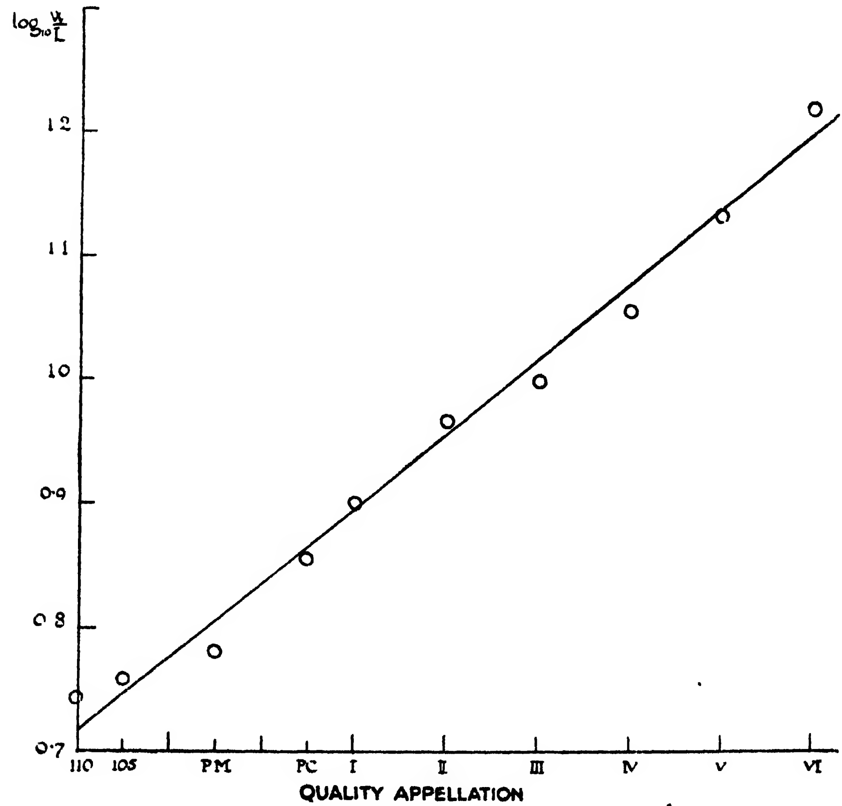

FIG. 2 French Standards for Combed Tops.

(1) From several places along each top small samples were taken between the thumb and finger and separated laterally from the top. Care was taken to maintain the fibres in the same relatively parallel position that they occupied in the top. In top manufacture there is obviously a very thorough mixture of the fibres composing the top, and this method of sampling was shown, by taking duplicate samples, to be very efficient.

(2) By gripping the bundle of fibres in the middle and gently combing towards each end with a dissecting needle, further parallelisation of the fibres was effected and at the same time a number of short fibres which would have to be discarded in the counting operation was eliminated. No short fibres, however, were removed from the middle section so that it will be realised that no kind of preferential combing took place which would affect the composition of the sample finally counted. The bundle of fibres was now placed in position on the instrument designed for cutting off a fixed length from the fibres. The bundle was then clamped in position with the fibres just straightened, and the fixed length cut from the middle portion of the bundle. Clearly the cut length of fibre employed must not be greater than the shortest length of fibre normally occurring in the tops, otherwise these short fibres will contribute nothing to the mean fineness and the result will be vitiated on this account. On the other hand, to cut to a length very much shorter than this yields no advantage, since by this means the percentage error in the length of the cut fibre is increased and the number of fibres which must necessarily be counted

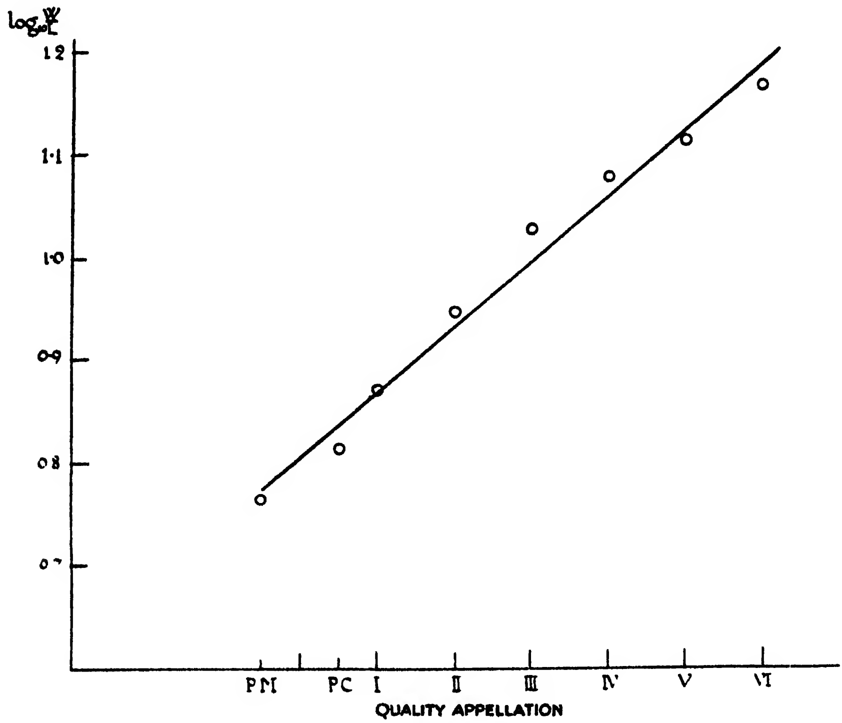

FIG 3 Belgian Standards for Combed Tops

out to give a weight determinable with the desired accuracy is much increased, with consequent extra expenditure of time and labour In the present work the fibres from the 36's–50's tops, and all corresponding qualities, have been cut to a length of 4 cm., while for qualities higher than 56's the cut length has been 3 cm. These lengths were shorter than the length of any fibres likely to occur in the respective tops.

(3) The counting operation consisted in placing the cut bundle of fibres with as little disturbance as possible on to a black velvet board and with suitable forceps separating fibre after fibre, laterally, from the bundle and placing them together in a group until the desired number has been counted out. By taking the fibres in turn from the side of the bundle, there was no danger of any preferential selection such as might have occurred if the fibres had been drawn from the end of the bundles. For the coarser qualities 500 fibres were counted out and 600 or 700 for the higher qualities. A duplicate sample was then prepared and counted out by exactly the same procedure. Care had to be taken, of course, in the counting operation to discard all fibres shorter than the fixed length.

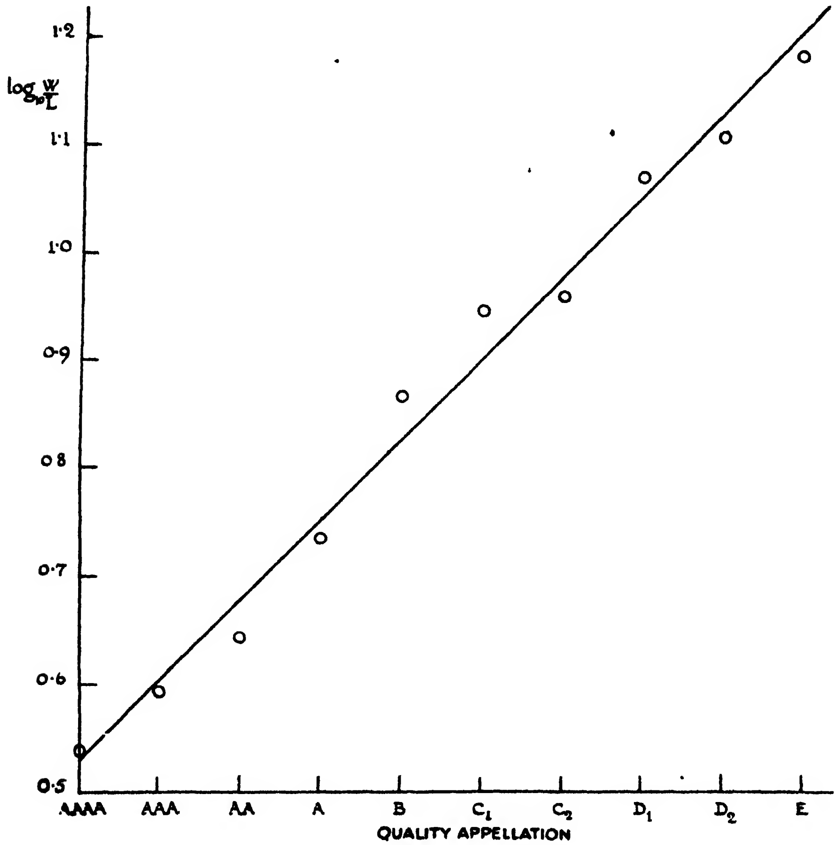

FIG. 4. German Standards for Combed Tops.

(4) The counted groups of fibres were rolled together by the finger into compact bundles which, it was found, did not separate when placed in liquid, and were washed in two changes of warm benzene (60° C.), followed by two rinsings in distilled water. In order to assist in the washing a small quantity of saponin was present in the first vessel of water. At the same time as the counted groups of fibres were washed a sample of approximately a gramme

weight from the corresponding top was dealt with in the same manner. The counted groups and gramme sample were then exposed together in a room of constant humidity and allowed to dry for a day or so. Afterwards, the counted groups were placed in weighing bottles and the larger sample placed in a regain bottle and their weights ascertained on a chemical balance weighing to 0·0001 gramme. The dry weight of the sample in the regain bottle was found, after drying in a stream of dry air at 105° C. had resulted in a constant weight for the sample. The corresponding dry weights of the groups of counted fibres were then calculated, and from these values was found the weight in milligrammes of 10 metres of fibre at a regain of 18¼ per cent.

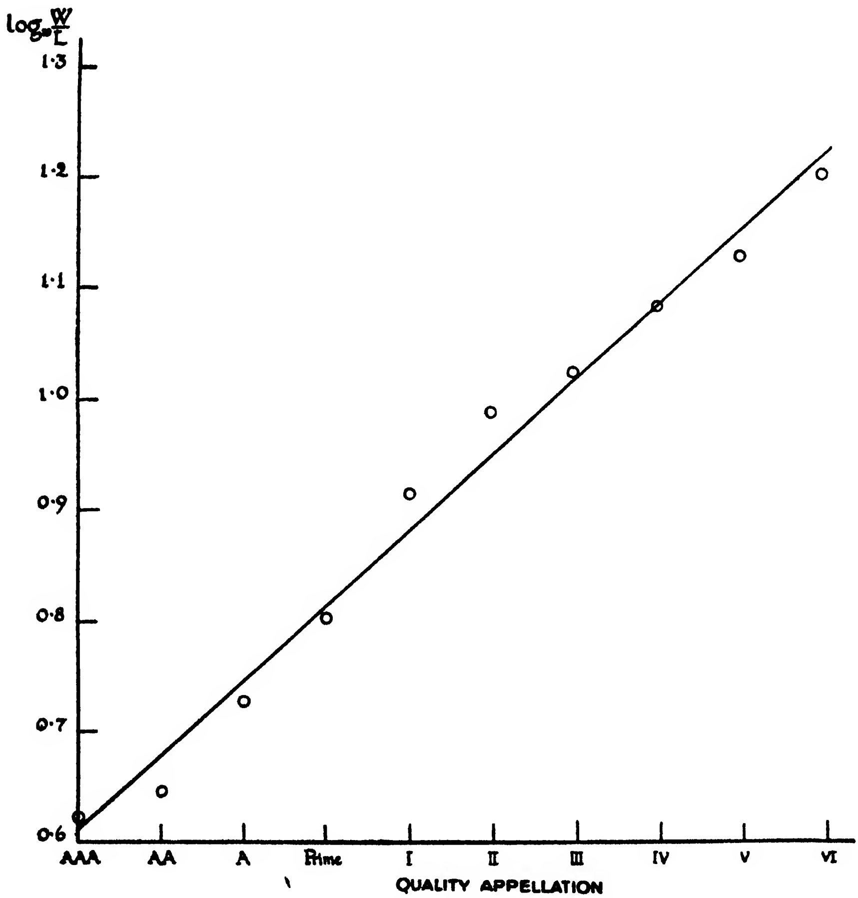

FIG. 5. Italian Standards for Combed Tops

In order to test whether washing in warm benzene was an efficient means of cleaning the fibre or not the following test was applied. Duplicate samples were washed as described above and a further counted sample was submitted to six hours' treatment with ether in a Soxhlet. The weight of the latter sample differed from the mean of the two ordinarily treated samples by an

amount less than the standard error of the mean, and therefore the more lengthy and elaborate washing treatment was considered unnecessary since it contributed nothing to the accuracy of the final result.

RESULTS

The detailed results, including those for the British selected tops, are given in the following tables—

Table I

British Selected Tops

Quality	Cut Length of Fibres in cm.	Number of Fibres	Weight of Samples in g.	Weight of 10 metres of Fibres in g.	Weight in mg. of 10 metres of Fibres at 18¼% Regain	Logarithm of Preceding Column
80's	2	500	0·00385	0·00392	4·64	·6665
		500	0·00402			
		1000	0·00779			
70's	3	500	0·00636	0·00426	5·04	·7024
		500	0·00645			
		1,000	0·01273			
64's	3	500	0·00758	0·00510	6·03	·7803
		500	0·00758			
		1,000	0·01549			
60's	3	500	0·00906	0·00606	7·17	·8555
		500	0·00897			
		1,000	0·01836			
58's	3	500	0·01006	0·00677	8·01	·9036
		500	0·00997			
		1,000	0·02062			
56's	3	500	0·01201	0·00808	9·55	·9800
		1,000	0·02437			
50's	5	500	0·02419	0·00988	11·69	1·0679
		500	0·02495			
	4	1,000	0·03975			
48's	4	500	0·02191	0·01108	13·10	1·1173
		500	0·02182			
		1,000	0·04494			
46's	4	500	0·02255	0·01134	13·41	1·1274
		500	0·02169		*14·88	*1·1727
		1,000	0·04663			
44's	4	500	0·02638	0·01290	15·25	1·1832
		500	0·02579		*17·16	*1·2345
		1,000	0·05099			
40's	4	500	0·02684	0·01371	16·21	1·2098
		500	0·02743		*17·67	*1·2472
		500	0·02801			
36's	4	500	0·02734	0·01329	15·71	1·1962
		500	0·02515		*18·44	*1·2657
		500	0·02726			

* Values computed from cross-sectional area measurements. Irregularity due to medullated fibres.

Table II

French Standards for Combed Tops

Fineness	Cut Length of Fibres in cm.	Number of Fibres taken	Dry Weights of Duplicate Samples	Mean Dry Weight of 10 metres in g.	Mean Weight in mg. of 10 metres at 18¼% Regain	Logarithm of Preceding Column
Cape—						
110	3	600	0·00851 0·00834	0·00468	5·535	·7431
105	3	600	0·00879 0·00862	0·00484	5·724	·7577
Croisé Prime ...	3	600	0·01100 0·01082	0·00606	7·168	·8554
Australian—						
Merino Prime...	3	500	0·00736 0·00761	0·00499	5·902	·7710
Merino I ...	4	500	0·01294 0·01260	0·00638	7·546	·8777
„ II ...	4	500	0·01508 0·01525	0·00758	8·966	·9526
„ III ...	4	500	0·01703 0·01703	0·00852	10·08	1·0033
„ IV ...	4	500	0·01966 0·01949	0·00979	11·58	1·0637
„ V ...	4	500	0·02386 0·02403	0·01197	14·16	1·1510
Buenos Aires—						
Merino Prime...	3	500	0·00767 0·00802	0·00523	6·186	·7914
Croisé Prime ...	3	500	0·00906 0·00915	0·00607	7·180	·8561
I	3	500	0·01079 0·01096	0·00725	8·576	·9332
II	3	500	0·01246 0·01281	0·00842	9·959	·9982
III	3	500	0·01293 0·01310	0·00868	10·27	1·0114
IV	3	500	0·01571 0·01554	0·01042	12·32	1·0907
V	3	500	0·01637 0·01672	0·01103	13·05	1·1154
VI	3	500	0·02028 0·02175	0·01401	16·57	1·2193
Afrique—						
I	3	500	0·00999 0·00982	0·00660	7·806	·8924
II	3	500	0·01115 0·01142	0·00752	8·894	·9491
III	3	500	0·01209 0·01174	0·00794	9·390	·9727
IV	3	500	0·01291 0·01309	0·00867	10·28	1·0109

Table III
Belgian Standards for Combed Tops

Fineness	Cut Length of Fibres in cm.	Number of Fibres taken	Dry Weights of Duplicate Samples in g.	Mean Dry Weight of 10 metres in g.	Mean Weight in mg. of 10 metres at 18¼% Regain	Logarithm of Preceding Column
120	3	600	0·00766 0·00748	0·00421	4·980	·6972
115	3	600	0·00818 0·00835	0·00459	5·429	·7347
110	3	600	0·00905 0·00871	0·00493	5·830	·7657
105	3	500	0·00791 0·00808	0·00533	6·304	·7996
Prime Merino ..	3	600	0·00877 0·00877	0·00487	5·760	·7604
Prime Croisé ...	3	600	0·01009 0·00983	0·00553	6·540	·8156
I	3	600	0·01175 0·01088	0·00629	7·440	·8716
II	4	500	0·01456 0·01543	0·00750	8·872	·9480
III	4	500	0·01778 0·01830	0·00902	10·67	1·0281
IV	4	500	0·01974 0·02108	0·01016	12·02	1·0797
V	4	500	0·02196 0·02196	0·01098	12·99	1·1136
VI	4	500	0·02473 0·02509	0·01246	14·73	1·1684

Table IV

German Standards for Combed Tops

Fineness	Cut Length of Fibres in cm	Number of Fibres taken	Dry Weights of Duplicate Samples in g	Mean Dry Weight of 10 metres in g	Mean Weight in mg. of 10 metres at 18¼% Regain	Logarithm of Preceding Column
AAAA	3	700	0·00620 0·00603	0·00291	3·442	·5369
AAA	3	700	0·00696 0·00696	0·00331	3·914	·5927
AA	3	600	0·00668 0·00668	0·00371	4·388	·6423
A	3	600	0·00840 0·00807	0·00458	5·418	·7338
B	3	600	0·01136 0·01101	0·00621	7·345	·8660
C_1	3	500	0·01134 0·01099	0·00744	8·800	·9445
C_2	3	500	0·01115 0·01149	0·00755	8·930	·9508
D_1	3	500	0·01439 0·01497	0·00979	11·58	1·0637
D_2	3	500	0·01610 0·01610	0·01073	12·69	1·1035
E	4	500	0·02561 0·02517	0·01270	15·02	1·1767

Table V

Italian Standards for Combed Tops

Fineness	Cut Length of Fibres in cm	Number of Fibres taken	Dry Weights of Duplicate Samples in g.	Mean Dry Weight of 10 metres in g	Mean Weight in mg of 10 metres at 18¼% Regain	Logarithm of Preceding Column
AAA	3	700	0·00771 0·00719	0·00355	4·200	·6231
AA	3	600	0·00666 0·00682	0·00374	4·424	·6458
A	3	500	0·00685 0·00668	0·00451	5·335	·7271
Prime	3	500	0·00810 0·00801	0·00537	6·352	·8029
I	3	500	0·01059 0·01025	0·00695	8·220	·9149
II	3	500	0·01233 0·01233	0·00822	9·722	·9878
III	3	500	0·01322 0·01356	0·00893	10·56	1·0238
IV	3	500	0·01519 0·01554	0·01024	12·11	1·0832
V	3	500	0·01712 0·01694	0·01135	13·42	1·1279
VI	3	500	0·02000 0·02035	0·01345	15·91	1·2016

Table VI

Table of Finenesses Obtained from the Standard Curves

British			French			Belgian			German			Italian		
Quality Appellation	Weight in mg. of 10 m. at 18¼% Regain	Equivalent diam. $\times 10^{-3}$ cm.	Quality Appellation	Weight in mg. of 10 m. at 18¼% Regain	Equivalent diam. $\times 10^{-3}$ cm.	Quality Appellation	Weight in mg. of 10 m. at 18¼% Regain	Equivalent diam. $\times 10^{-3}$ cm.	Quality Appellation	Weight in mg. of 10 m. at 18¼% Regain	Equivalent diam. $\times 10^{-3}$ cm.	Quality Appellation	Weight in mg. of 10 m. at 18¼% Regain	Equivalent diam. $\times 10^{-3}$ cm.
80	4·44	1·92	110	5·24	2·08	Prime Merino	5·92	2·21	AAAA	3·38	1·67	AAA	4·08	1·84
70	5·19	2·07	105	5·61	2·16	Prime Croisé	6·86	2·38	AAA	4·01	1·82	AA	4·77	1·99
64	6·08	2·24	Prime Merino	6·43	2·31	I	7·39	2·47	AA	4·75	1·98	A	5·56	2·15
60	7·09	2·42	Prime Croisé	7·37	2·47	II	8·57	2·66	A	5·63	2·16	Prime	6·50	2·32
58	8·28	2·62	I	7·89	2·56	III	9·94	2·87	B	6·67	2·35	I	7·58	2·51
56	9·68	2·83	II	9·04	2·74	IV	11·52	3·09	C_1	7·91	2·56	II	8·85	2·71
50	11·31	3·06	III	10·36	2·93	V	13·36	3·33	C_2	9·38	2·79	III	10·34	2·93
48	13·21	3·31	IV	11·88	3·14	VI	15·49	3·58	D_1	11·11	3·03	IV	12·06	3·16
...	...	...	V	13·62	3·36	...	...	...	D_2	13·17	3·30	V	14·08	3·42
...	...	...	VI	15·60	3·59	...	...	...	E	15·61	3·60	VI	16·44	3·69

TREATMENT OF RESULTS

The graphs show the result of plotting the logarithm of the mean fineness against the successive quality designations for each country and also the line representing the best linear relationship between fineness and quality. The relationships are expressed by the following set of equations—

British ... ... $\text{Log}_{10} \frac{W}{L} = 0{\cdot}068x + 0{\cdot}44.$

French ... ... $\text{Log}_{10} \frac{W}{L} = 0{\cdot}059x + 0{\cdot}66.$

Belgian ... $\text{Log}_{10} \frac{W}{L} = 0{\cdot}064x + 0{\cdot}74.$

Italian ... ... $\text{Log}_{10} \frac{W}{L} = 0{\cdot}067x + 0{\cdot}54.$

German... ... $\text{Log}_{10} \frac{W}{L} = 0{\cdot}074x + 0{\cdot}46.$

The significance of x in the above equations varies of course with each country and the following scheme indicates the values of x which have been assigned to the various qualities.

	Quality Designation										
	80's	70's	64's	60's	58's	56's	50's	48's			
British ... $x=$	3	4	5	6	7	8	9	10			—
	110	105	100	P M	P C	I	II	III	IV	V	VI
French ... $x=$	1	1·5	2	2·5	3·5	4	5	6	7	8	9
	P M	P C	I	II	III	IV	V	VI			
Belgian . $x=$	0·5	1·5	2	3	4	5	6	7	–	—	
	AAA	AA	A	P	I	II	III	IV	V	VI	
Italian . $x=$	1	2	3	4	5	6	7	8	9	10	
	AAAA	AAA	AA	A	B	C_1	C_2	D_1	D_2	E	
German . . $x=$	1	2	3	4	5	6	7	8	9	10	

The values given to x are quite arbitrary and are merely for the purpose of evaluating the constants of the equations. They may be replaced by any other set of values provided that the relative intervals between the numbers representing the qualities remain unaltered. These intervals, with the exceptions we shall now mention, are all equal. The exceptions occur in the French and Belgian scales and are due to the introduction at one part of the scale of intermediate qualities. Thus, in the French scale the measurements make it clear that the qualities 110, 100, Prime, I, II, etc., form a series obeying the logarithmic law and that the qualities 105, Prime Merino, and Prime Croisé are intermediate qualities. They have accordingly been assigned the values of $x=0{\cdot}5$, $2{\cdot}5$, $3{\cdot}5$, and are then found to fall into agreement with the law governing the rest of the qualities. The Belgian classification likewise forms a regular series below the Prime quality if we assign the qualities Prime Merino and Prime Croisé to intermediate positions on either side the quality Prime. The qualities higher than Prime on the Belgian scale have for the time being been left out of the scale of standards. This is the only case in which overlapping in respect to fineness occurred, and here, as the figures will indicate,

the mean finenesses of the Prime Merino and Prime Croisé approximate to those for the 110 and 105 qualities respectively Repeat samples of the Prime Merino and Prime Croisé were obtained and measurements on these confirmed the previous results. An explanation of this anomaly is not as yet forthcoming.

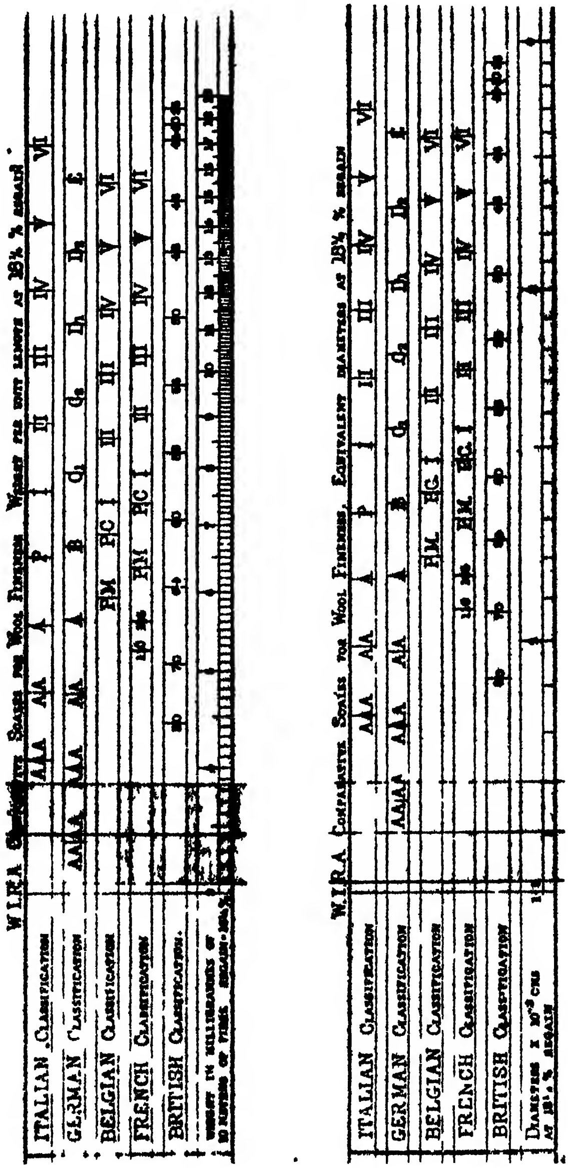

PLATE I

From the lines on the graph, or their equations, a set of values may now be found for each country which will represent the mean values of fineness for the different qualities The values are shown grouped together in Table VI.

Here also are tabulated, for the convenience of workers using "diameter" or fibre width as a measure of fineness, the "equivalent diameters" calculated on the assumption of circularity of fibre cross-section.

A composite scale (Plate I) has been constructed presenting the data contained in Table VI in a more convenient form. The different national scales are arranged collaterally and a cursor makes it possible to transfer from one scale to the other or to the absolute fineness, in mg. for 10 metres, set out on a logarithmic scale at the base. The other side of the scale shows the same information set out above a scale showing "equivalent diameters."

A comparison of the results obtained above with those obtained by continental workers is of interest. In the case of the French tops the values obtained by compounding the results from the several ranges of tops supplied to us yield a series which is consistently higher than the series published by M. M. Dantzer and Roehrich. The technique employed in the two methods is much the same, but in the present work it has been deemed preferable to base all weights on the true dry weight of the wool rather than on its weight while contained in a chamber of more or less constant humidity.

A direct comparison with the results obtained by German workers is not possible since in their case the fibres were not cut but measured whole. The longer fibres, therefore, contribute more to the final result than the shorter ones.

Italian measurements are only available in terms of fibre width. A very fair agreement, however, seems to exist between the "equivalent diameter" calculated from the weight/length ratio and alternative members of the series of values of fineness put forward as the Italian scale of fineness by Commander Schneider.

The author wishes to record his thanks to the Director of Research, Dr. S. G. Barker, for his continued interest in the work; to Mr. H. T. Tulloch, Secretary of the Bradford Chamber of Commerce, for his kindness in obtaining representative samples from each of the countries in question; and to Miss A. L. Walker, for her able assistance throughout the investigation.

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40—SAMPLING INSTRUMENTS TO DETERMINE FLEECE DENSITY IN SHEEP

By Robert H. Burns and W. C. Miller

INTRODUCTION

The term "density" is defined as "closeness of substance," which in the purely physical meaning is designated by specific gravity. In fleece analysis on the sheep, however, density is usually interpreted as meaning the total amount of wool fibre growing on a definite unit area of skin, usually on the living animal. Density, or the number of follicles on a certain area of histological sections of the pelt, was first described by Nathusius (1866) and has more recently been used by Tänzer (1928) in histological studies of the development of the follicle and the pattern of the fibre groups occurring in Karakul sheep. The pelt method of density determination is more adaptable to histological study of skin sections and can have little or no application to studies of fleece analysis in pure-bred or commercial flocks.

Density of fleece is one of the most important economic fleece characters and is closely associated with fineness and crimp. Mentzel (1892) was one of the first writers to point out the commercial importance of density of wool fibres per unit area on the skin. Hultz (1927) and Hultz and Paschal (1930) have pointed out that density is one of the most important of the measurable fleece characters, as shown by a statistical study of fleece measurements made on prize-winning Rambouillet sheep. The very definition of density as the quantity of wool per unit area, indicates its importance from a commercial standpoint. The Australian Merino, one of the finest products of the art and science of sheep breeding, is, as shown by figures published by Burns (1929), a striking instance of how great density has by careful control been combined with long fibre, two characters not ordinarily associated, since as a fleece becomes more dense it usually becomes shorter.

In studies of fleece density on the living sheep, the primary requisite, in order to have comparable figures, is to have a sample taken from a definite unit area on the skin. The latter part of this paper is concerned with instruments and methods for securing the sample, but it is convenient here to indicate in some degree of detail methods of determining density as an introduction to the description of the instruments.

Methods of Expressing Density

When the sample has been removed from a unit area of the skin, has been cleansed, and detailed determinations made upon a fraction of it (which may conveniently vary between 100 and 500 fibres), the data may be used to express density per unit area in a number of ways. The requisite data consist of the weight of the sample and of the fraction, the mean thickness of the fibres in the fraction, their number, and the average stretched length per fibre. Since combinations of length and weight, or weight and fineness are more convenient when expressed in the metric system, this has been employed exclusively.

For convenience, for brevity, and to avoid confusion, the following symbols have been adopted—

N = Total number of fibres per unit area (1 sq. cm.) of skin.

L = Total stretched length of wool fibre per 1 sq. cm. of skin (in centimetres).

W = Clean, dry weight of wool per 1 sq. cm. of skin (in grammes).

$\triangle$ = The sum of the cross-sectional areas of the wool fibres per 1 sq. cm. of skin. (This is a comparative rather than an absolute value.) Result is in square centimetres.

$\square$ = The volume of wool growing upon 1 sq. cm. of skin (in cubic centimetres).

ML/W = Metre-length-weight ratio, i.e. the weight of 1 m. length of wool (in grammes).

The corresponding symbols for the fractions are the lower case of those for the total sample (e.g. *n*, *w*, etc.; but *l* is mean fibre length of the sample).

The values of the symbols can be obtained by the following alternative simple formulæ, which may be used as a check upon each other if desirable—

$$N = (1)\ \frac{\text{Total weight of wool (W)} \times \text{number of fibres in fraction } (n)}{\text{Weight of wool in fraction } (w)}$$

$$= \frac{W \times n}{w}$$

$$\text{or } (2)\ \frac{\text{Total length of wool fibre (L)}}{\text{Mean fibre length } (l)}$$

$$= \frac{L}{l}$$

$$L = (1)\ \text{Mean fibre length } (l) \times \text{total number of fibres (N)}$$

$$= l \times N$$

$$\text{or } (2)\ \frac{\text{Total weight wool (W)} \times \text{mean fibre length } (l) \times \text{number of fibres in fraction } (n)}{\text{Weight of wool in fraction } (w)}$$

$$= \frac{W \times l \times n}{w}$$

W is obtained by direct weighing.

$\triangle$ = Mean cross-sectional area per fibre $[\pi \times (\frac{1}{2}f)^2]$ × total number of fibres (N).

$= \pi \times \left(\frac{f}{2}\right)^2 \times N$, — where f = the mean diameter per fibre measured in centimetres. For simplicity and since the value of $\triangle$ is not absolute, it is suggested that for comparative purposes the formula should be simplified by eliminating the constant π. The formula would then be

$$= \left(\frac{f}{2}\right)^2 \times N.$$

$\square$ = Area × mean fibre length (l).

$= \triangle \times l.$

$$ML/W = \frac{100 \times \text{weight of wool in fraction } (w)}{\text{Mean fibre length } (l) \times \text{number of fibres in fraction } (n)}$$

$$= \frac{100 \times n}{l \times n}$$

Obviously there are various other ways of arriving at the values for these symbols (e.g. displacement volume may be computed by using the figure for specific gravity of wool—1·3—divided into the absolute dry weight of the sample), but the writers have found them less convenient in use than those given.

For illustration a typical example may be taken as follows—

Cheviot Ewe—Mid-shoulder sample.

$$\begin{aligned} \text{Unit area} &= 1 \text{ sq. cm.} \\ W &= \cdot 2022 \text{ g.} \\ w &= \cdot 018 \text{ g.} \\ l &= 9{\cdot}974 \text{ cm} \\ n &= 100 \text{ fibres.} \\ f &= \cdot 00503 \text{ cm.} \end{aligned}$$

$$N = (1)\ \frac{W \times n}{w} = \frac{\cdot 2022 \times 100}{\cdot 018} = 1123 \text{ fibres.}$$

$$\text{or } (2)\ \frac{L}{l} = \frac{11200{\cdot}8}{9{\cdot}974} = 1123 \text{ fibres.}$$

$$L = (1)\ l \times N = 9{\cdot}974 \times 1123 = 11200{\cdot}8 \text{ cms.}$$

$$\text{or } (2)\ \frac{W \times l \times n}{w} = \frac{\cdot 2022 \times 9{\cdot}974 \times 100}{\cdot 018} = 11204{\cdot}1 \text{ cms.}$$

$$\triangle = \left(\frac{f}{2}\right)^2 \times N = (\cdot 002515)^2 \times 1123 = \cdot 0071^*$$

$$\square = \triangle \times l = \cdot 0071 \times 9{\cdot}974 = \cdot 0708^*$$

$$ML/W = \frac{w \times 100}{l \times n} = \frac{\cdot 018 \times 100}{9{\cdot}974 \times 100} = \cdot 001805 \text{ grm.}$$

Much work still remains to be carried out before it will be possible to suggest whether some or all of these methods of determining density, or more probably which combinations of them, should be employed for routine analysis of fleece samples in genetical or other breeding experiments or in schemes of fleece improvement. To some extent the particular index of density will always depend upon the type of wool grown by the sheep and the ultimate manufacturing purpose for which it is best suited.

It will be noted that all of these methods of designating density of fleece depend on defining a unit area on the skin from which the wool sample is removed. Thus the first step is the design of a suitable instrument for this purpose which will be positive in action and simple to use.

Earlier Instruments

In order that the reader will have some idea of the previous instruments and methods which have been used for the determination of fleece density a short description of some of these will be of interest.

Mentzel (1892) was probably the first to describe an instrument for determining fleece density. This instrument, shown in Fig. 1, was a modified caliper, with the throat graduated and possessing a thrust collar, which could be screwed up to press the fibres within the jaws of the caliper into a compact mass and giving an approximate but direct reading of the sum of the cross-sectional areas of the wool fibres. This instrument was designed to thrust

* If an approximate value in $cm.^2$ or $cm.^3$ is desired for these values it is necessary to include the value of the constant π in determining the $\triangle$.

into the fleece on the sheep's body and obtain an index of fleece density without removing any wool. It had the obvious disadvantage that in the compression of the wool fibres it was impossible to avoid measuring a certain indefinite amount of empty space between the wool fibres.

Burns (1925) described a caliper method for defining ½-in. square areas on the skin, separating the wool fibres at the margins of the area. The instrument used consisted of a pair of engineers' outside measuring calipers with each point ground down at its tip.

Nordby (1928) described a modification of the engineers' calipers which he named the Idaho Wool Caliper. This instrument, shown in Fig. 2, consisted of two pairs of calipers, one mounted on the other, with the jaws crossing at right angles.

Duerden (1929) described an instrument, shown in Fig. 3, which consists of a forked caliper with a pair of cross pins mounted as a unit, passing through holes drilled at right angles through the jaws of the caliper.

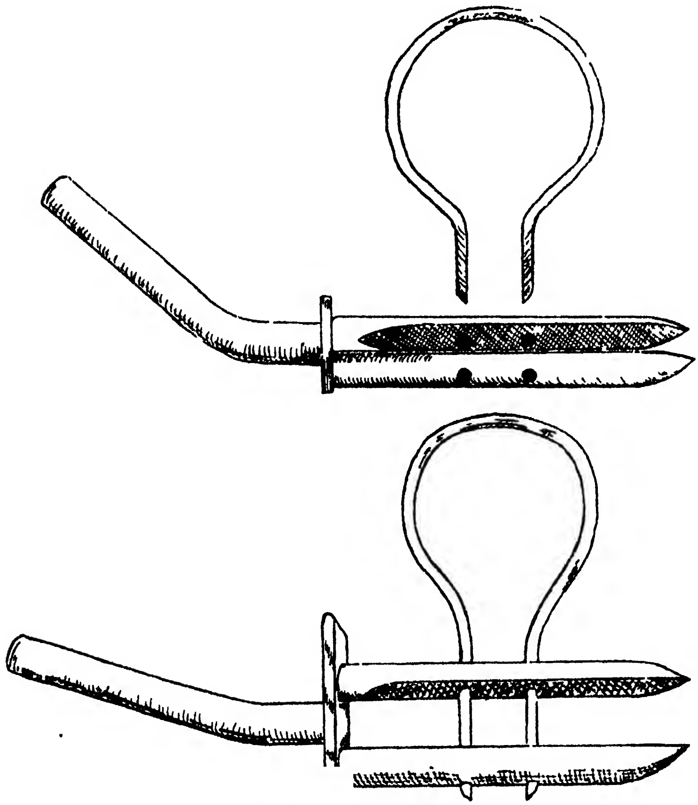

FIG. 3—Wool Caliper described by Duerden (1929).

Burns (1930) described a pair of altered-leg dividers in which the legs were parallel throughout the last inch of their length.

Hardy (1930) advised the writers of a method which he has used successfully. It consists of the use of an electric clipper with jaws 1 in. wide. A swath is clipped from a selected area and the length of the swath is measured.

The absolute dry weight of the clipped sample is determined and the stretched fibre length is measured to allow for variation in seasonal growth of fibre in different fleeces.

Nichols (1930) advised the writers of a photographic method for the determination of fleece density. The wool is clipped from an area of skin, approximately square and of such a size that the bare spot of skin can be easily photographed. In the middle of the cleared area is fastened a piece of square material, such as a postage stamp, whose dimensions are accurately known. This skin area is then photographed and from the finished photograph the area of skin can easily be calculated by proportional measurements. The amount of wool clipped from the area is preserved and used subsequently for density determination.

Küsebauch (1931) described an instrument for determining the fineness of samples of wool by measuring the diagonal of a bundle of 100 fibres which had been sorted by length. This instrument was named the Rapid Lanometer and might be useful for density determination by cross-sectional area.

All of the instruments and methods described have dealt with square or rectangular areas. Each instrument had certain disadvantages, particularly in that they were either not positive enough in operation or they were too cumbersome to ensure accuracy. The need for an instrument which would be positive in action and simple to use has led to the design of the Wyedena and Wyedesa Fleece Calipers,* the latter being an improvement on the former.

THE WYEDENA FLEECE CALIPER

This instrument is shown in Figs. 4 and 5. It is a forked caliper with a pair of cross-pins mounted as a unit, which fit into holes at the top of the handle when not in use—a very useful feature. The particular instrument shown was made with the points of the jaws ½ in. apart, but could be made with a 1-cm. space between the jaws if it was desired to use the metric system. The general design and detailed angles and dimensions are well shown in the figures.

Technique of Sampling with the Wyedena Fleece Caliper

After the sheep has been laid on a table and the area to be sampled has been selected, two long right-angled "partings" are made in the fleece, in the form of a large L. In most sheep the fleece "parts" most easily along a line parallel with the limbs, or from dorsal to ventral regions. Then along the short leg of the L-shaped "parting" a swath of wool about 3 cm. wide is clipped to facilitate the insertion of the cross-pins. In a very long dense-woolled fleece it may be necessary to cut a similar swath along the long leg of the L so that the heel of the instrument can rest flat on the skin and the sampling operation can be carried out with more ease and accuracy. The form of the part and the position of the "swaths" is shown in Fig. 6. The cross-pins are now taken from their recesses in the top of the handle and laid out ready for use. The caliper is introduced so that the jaw on the side from which the cross-pins will be inserted is only distant by a few fibres' space from the edge of the swath on the short leg of the "parting." Now the cross-pins are inserted

* Members of the wool research laboratories of Wyoming, Edinburgh, and South Africa have collaborated in the design of these instruments and the names are combinations of the abbreviations for these laboratories.

through the holes in the jaws of the caliper thus parting the wool growing on a ½-in. square area of skin surface. This position is shown in Fig. 7.

Once the cross-pins are in place, the sample can be separated from the surrounding wool with a quill or dissecting needle. A large porcupine quill or a piece of hard wood the size of a large lead pencil with a sharp point is ideal for dissecting wool. When the sample has been dissected it is grasped with the fingers, and clipped off close to the skin. A pair of surgeon's 8 in. scissors with blades angled at 45° on the flat will be found very useful in clipping off the wool close to the skin.

THE WYEDESA FLEECE CALIPER

When taking samples with the Wyedena Fleece Caliper the great advantage of some method of clamping the wool, after the step shown in Fig. 6, became quite evident. The great difficulty was to design an instrument in which the jaws were parallel and rigid when open and yet would close to clamp the wool. With a clamping type of fleece caliper, all the wool in the clamp could be clipped oft and the sample separated from the surrounding wool in the laboratory which would be quite an advantage over dissecting the sample on the sheep's body. To meet these requirements the Wyedesa instrument has been devised. This is shown in different perspectives in Figs. 8 to 10. It will be noted that the fundamental principles of the Wyedena Fleece Caliper are retained in the Wyedesa instrument, the difference being the addition of the clamping feature in the latter.

Technique of Sampling with the Wyedesa Fleece Caliper

The general procedure of sampling is exactly the same as outlined for the Wydena Fleece Caliper until after the cross-pins have been inserted through the jaws. In practice it has been found expedient for one person to hold the caliper while another inserts the cross-pins. At this stage the caliper is pulled up about ½ in. from the skin and clamped. The caliper is then laid down with the cross-pins on top so that they cannot slip out from its jaws. This position is shown in Fig. 11. The caliper acts as a weight pulling the wool, so that it is easily clipped off close to the skin. One operator opens the caliper and holds it up with the proximal end of the sample uppermost, and the other separates the fibres away from the cross-pins with a quill. The fibres have already been separated for the first ½ in. of their length when the caliper was drawn up from the skin with the cross-pins in place. The appearance of the sample at this stage is shown in Fig. 12. The sample is completely separated from the surrounding wool by grasping it where already parted at the proximal end and stripping away the rest of the wool which does not belong to the unit area. However, quite often it will be found difficult to strip the extraneous wool off in this way, due to numerous cross-fibres or to cotting of the wool. In such cases a small rubber band or a small clip is fastened around the ½-in. section of the proximal end of the sample already separated, leaving the final dissection of the sample to be finished in the laboratory. The advantage of this feature is evident to anyone who has sampled sheep in a paddock. In the great majority of wools there are very few cross-fibres next to the skin and it is easy to pull the caliper up one ½ in. from the skin and an excellent "part" results as shown in Fig. 12, after the sample has been clipped from the skin.

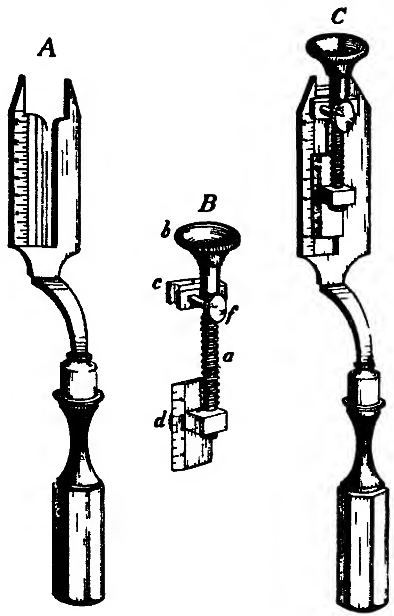

FIG 1—Mentzel's Wolldichtigkeitmesser—Mentzel's Wool Density Measure

(Block by courtesy of Messrs Urban and Schwarzenberg, Berlin)

Fig [illegible] The Idaho Wool Caliper The instrument illustrated is a slight modification of the original Idaho Wool Caliper

Fig 4 The Wyodena Fleece Caliper viewed from above The holes in the top of the handle are for storing the pins when not in use Pins are inserted in jaws

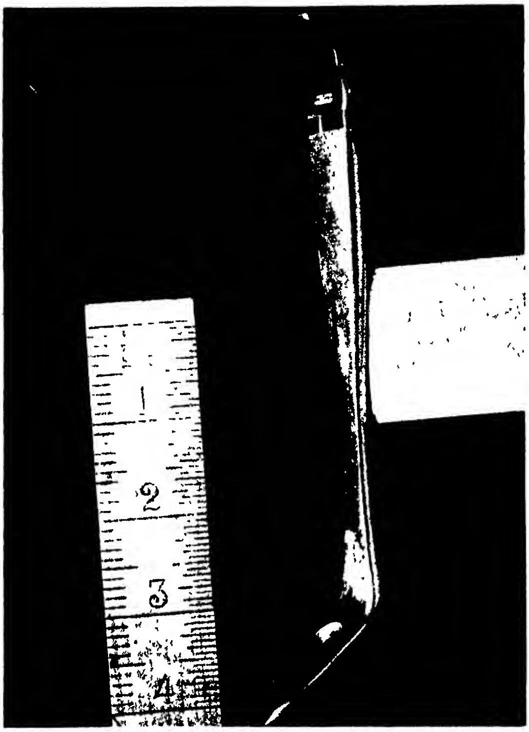

FIG. 5 –Wyedena Fleece Caliper, viewed from the side.

FIG. 6 –The "L" shaped partings with the "swaths" of wool removed and the area ready to be sampled.

FIG. 7. The Wyedesa Fleece Caliper in position on the skin with the cross pins inserted through the forked jaw separating the wool growing from a square area on the skin.

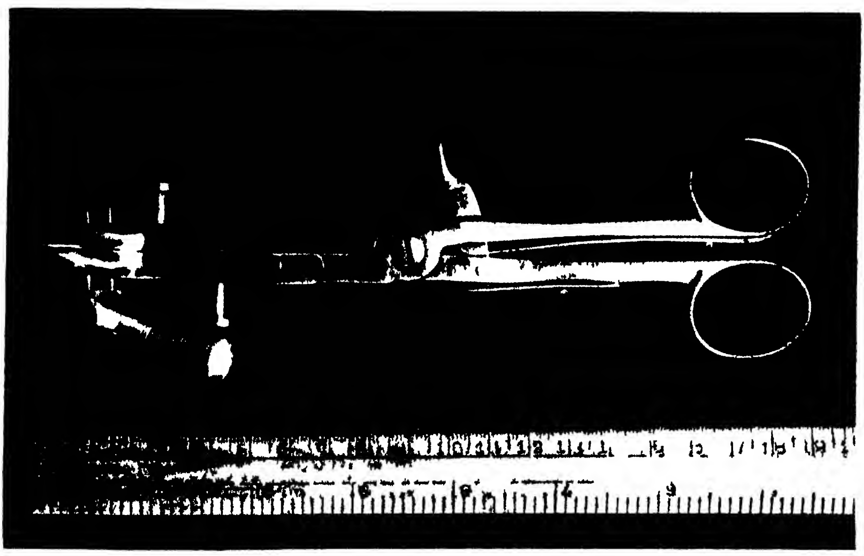

FIG. 8. Wyedesa Fleece Caliper (Original Model). View from the front and top with jaws closed, and cross pins inserted through forked jaws.

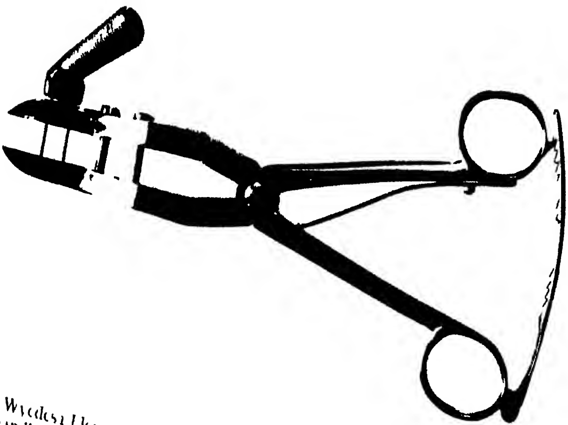

Fig. 9 Wyedesa Fleece Caliper (Modified Model). The ratchet catch is placed on top of the handle and with more notches gives opportunity for different amounts of pressure when the jaws are closed. The handle of the pins is hollowed out making it much lighter in weight and not so apt to fall out when inserted in the jaws.

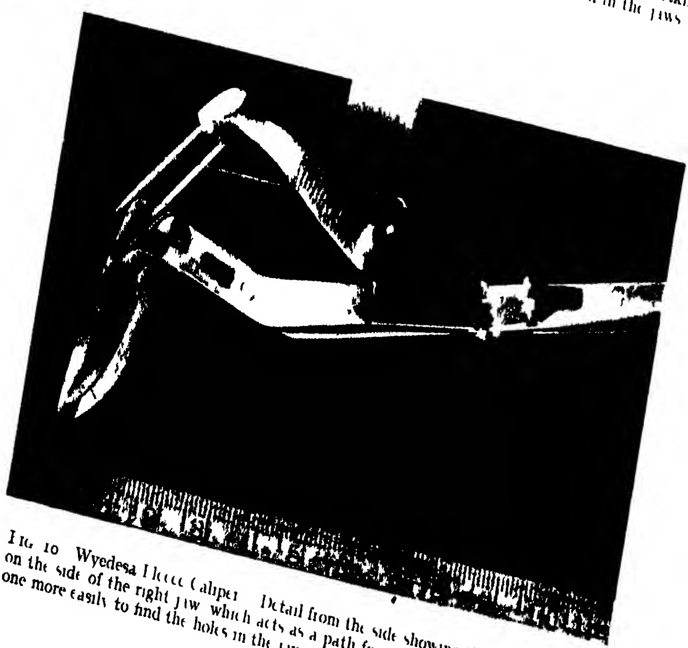

Fig. 10 Wyedesa Fleece Caliper. Detail from the side showing the guiding groove on the side of the right jaw which acts as a path for the tips of the pins enabling one more easily to find the holes in the jaws when the caliper is in place on the skin.

FIG. 11. Wyedesa Fleece Caliper. The caliper is inserted into the fleece and the cross pins pushed through the holes in the jaws. Then the caliper is pulled up one half inch from the skin and clamped with the sample and some of the adjacent wool grasped between the jaws.

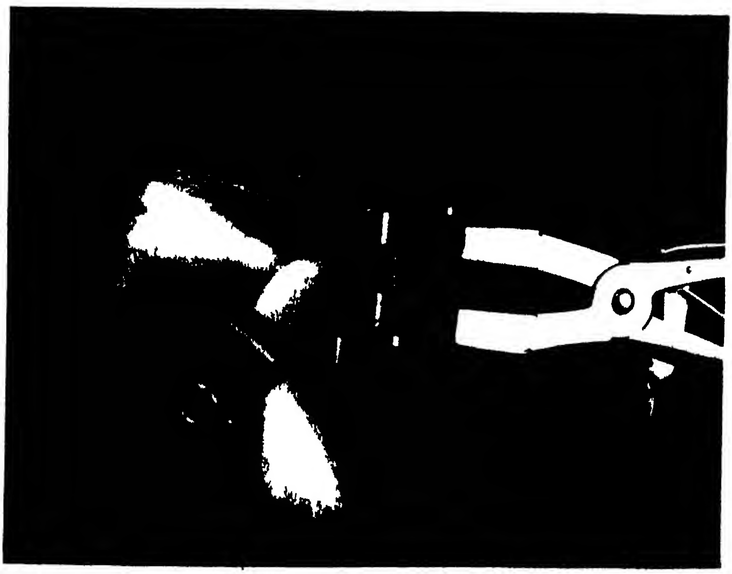

FIG. 12. Wyedesa Fleece Caliper. The sample has been clipped off close to the skin. The caliper with the jaws open is held with the proximal end of the sample uppermost and the sample is then dissected along the sides partially separated previously by the cross pins when the caliper was pulled up from the skin.

FIG. 13—Showing the first part made in the fleece. The quill has been moved to one side to show the actual skin line, and the second quill is *in situ*, but the wool has not been separated. The cross-action forceps are clamping the wool to the outside of the proposed triangle.

FIG. 16—Tri-Prong-Divider with the blades open.

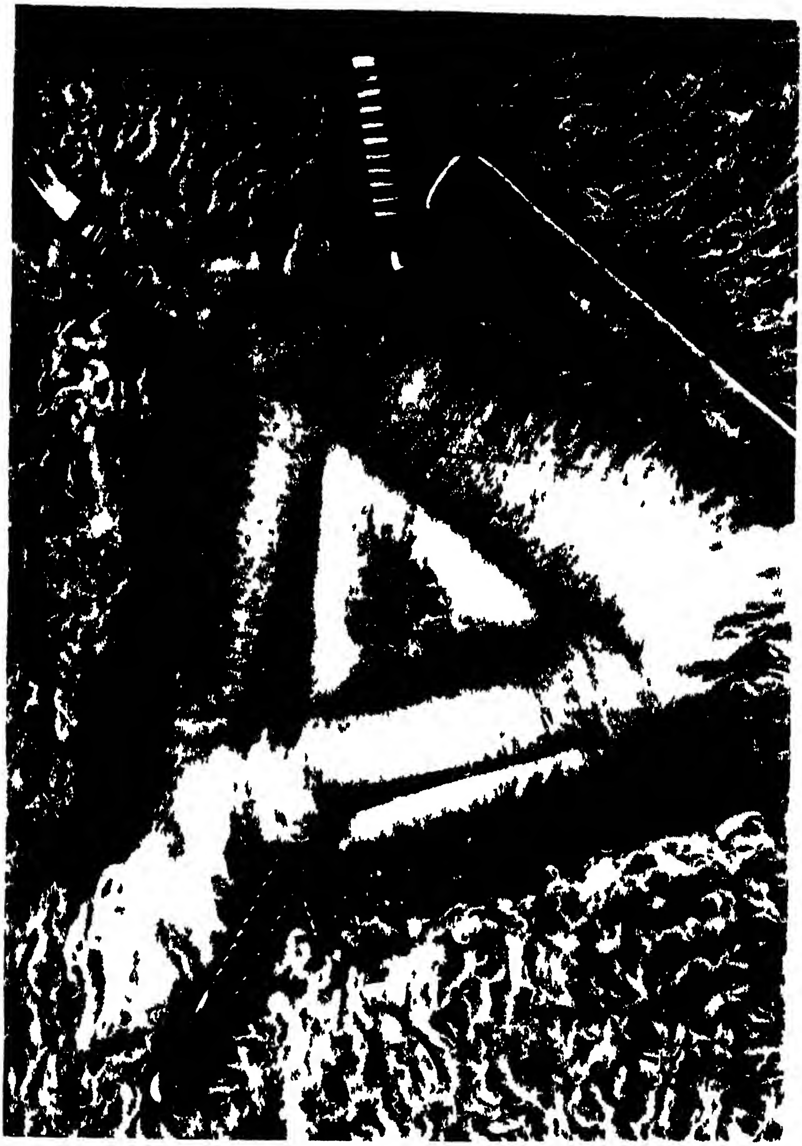

FIG. 14. The triangular tuft of wool has been demarcated from the surrounding wool and a rubber band slipped on to it. Cross-action forceps hold the outer walls of wool cleanly apart from the sample. To facilitate photographing lead weights were laid around the triangle to expose the parting lines better.

FIG. 15. The triangular tuft which constitutes the sample has been clipped off and is lying on the surface of the fleece. A single dot of Indian ink larger than is used in practice can be seen at each angle. The distances between these are recorded on the envelope which contains each sample.

TRIANGULAR METHOD OF DETERMINING DENSITY

The principle involved in this method was first suggested by Mr. J. A. Fraser Roberts who contributes the following note—

"Some years ago I experimented with methods employing a rectangular area on the skin. My colleague, Dr. A. Stevenson, now of the Scottish Woollen Technical College, Galashiels, suggested that a much better principle would be to make only a single parting at a time and to make the area triangular. I found that, using a fine knitting needle, it was entirely practicable rapidly to separate off a triangular area and remove the wool. It appeared to be possible to make the sides of the triangle quite straight. I have used the method in connection with one or two investigations and am very glad that Mr. Miller has found this a very useful technique and has been able to elaborate and perfect it in so satisfactory a manner."

The principle depends upon the fact that to make a perfectly straight part or shed in the fleece which shall be of adequate length it is advisable to employ only one dividing agent at a time. The reflex sensory-motor system of the sheep's skin is so well developed that cutaneous irritation resulting from the passage across it of an agent which, used carelessly or roughly, may prick the skin, may readily cause a reflex contraction of the cutaneous muscle, with consequent disturbance of the outlines of the area from which the sample is to be removed. In the method to be described it is believed that much of this error is avoided.

The method is of most use for the long-woolled breeds, where separation of tangled staples of wool is difficult under any conditions and impossible under some. It has been found inadvisable to employ any form of instrument in which the points which must separate the wool are short or thick for sheep such as the Scottish Mountain Blackface, Lincoln, Oxford, Cotswold, etc., breeds, and since much of the work in progress at this department includes the use of long-woolled breeds, the triangular method has been devised primarily for them. At the same time, in the hands of Mr. Roberts, and our own, the method has given very satisfactory results in short-woolled sheep—Cheviot, Half-bred, Welsh Mountain, Suffolk, etc.

Instruments—The equipment is simple in the extreme; it consists of an ordinary steel ruler—preferably graduated in sixteenths of an inch along one edge and having a centimetre scale along the opposite edge; a pair of dividers (preferably opening and shutting by a screw action); two ordinary steel knitting needles, each with one end made somewhat sharper than usual, or, even preferably, two large porcupine quills; and three pairs of cross-action aural forceps. These latter are not essential, but they facilitate keeping the surrounding wool from the field of operation. Ordinary black Indian ink, or an indelible pencil, may be used to delineate the corners and edges of the triangle, or if the exact area must be permanently marked for future reference, an electric tattooing machine may be used. Rubber bands are a convenience to slip round each isolated tuft of wool, and a series of envelopes serve as handy receptacles for the samples.

Principle—The principle of the method is that of isolating a triangular tuft of wool from the rest of the fleece in such a way that the sides are straight, the angles cleanly defined, and the divisions in the wool made with as little breaking or tearing of the fibres as possible, consistent with complete separation of the fibres from each other.

Choice of Site—Samples can, by this method, be removed from almost any part of the surface of the body which will give a level flat triangle, of the requisite size. Probably the most convenient body region for ordinary routine sampling is an area on the right or left side of the sheep lying over the ribs. In this situation there should be no difficulty in determining anatomical landmarks.

Whatever choice of site is made it should be remembered that if only one sample is required from each sheep the sides of the triangle should be at least 2½–3 in. long if a fairly large sample is required. The smallest sized triangles used in Edinburgh (in a long series of observations made on each sheep at weekly intervals) were of 1·5 to 2·0 cm. length on each side. It is suggested that triangles smaller than these should not be used.

Method—The sheep is secured in the appropriate position on a table for preference. The area from which the sample is to be taken is determined by palpation of bony prominences, and one of the knitting needles (or porcupine quills) is introduced into the fleece until it meets the skin. It is then passed straight along the surface of the skin firmly but gently. It will be found that the line through the wool will not be straight until the needle has entered the wool for a distance of an inch or so; it is consequently necessary to commence the line at least 1 in. below the estimated angle of the triangle.

The needle is now raised (with the point as a fulcrum) ½ in. to 1 in. up from the skin and the wool divided, either with the fingers, or by another needle or quill, into two walls. A pair of cross-limbed forceps is slipped on to that wall which is to lie outside the triangle and separate from it. This serves to preserve the division in the wool already made and prevent entanglement of fibres which constitute the sample, by those outside it.

A second needle or quill is next inserted into the fleece, as shown in Fig. 13 in the same manner 1 in. or more behind the line of the first one and in such a direction that it will form an angle of about 60° with it. Following the same procedure as is described above, a second side of the triangle is demarcated, and the wool to the outside of it secured out of the way by a second pair of cross-limbed forceps. In the same way the third side is prepared and the wool outside it also secured by the third pair of forceps.

It is sometimes convenient to insert the second and third quills immediately after the first side of the triangle has been demarcated; in this way any gross misestimation of the angles can be corrected by withdrawing one and reinserting it more appropriately. It is necessary to emphasise that each needle or quill as it is being inserted must be pushed straight along its track with its point pressed lightly but firmly on the surface of the skin. Each point must not be allowed to rise from the skin level by even a fraction of an inch, or a false and irregular line will result. We believe that upon the careful observance of this rule depends the successful use of the method.

A triangular area of wool is now isolated (Fig. 14). Its angles are approximately of 60° and it is therefore practically equilateral in outline. For convenience and to preserve the identity of the staples which compose it and to ensure that its component fibres will maintain their contiguity and relationships (especially important in a fleece which is undergoing a process of shedding of some of its fibres) the triangular tuft should have a rubber band slipped over it and arranged fairly near its base; this also aids in keeping the

sample rigid while it is being clipped off subsequently. For very long wools, such as those of the Lincoln, Oxford, or Cotswold, etc., two or more rubber bands may be advisable.

The sample is now removed from the skin by clipping with scissors, or it may be removed by cutting with a sharp razor blade. By the latter method there is some risk of injuring the skin if the sheep struggles, or if the skin happens to be pulled up into a fold, but otherwise the sharp razor when used with care is rapid and satisfactory when length of fibre is being studied.

When the sample has been removed, or before if necessary, the three sides of the triangle are measured with the screw-dividers and their dimensions noted. It may be convenient for extreme accuracy, to put a dot of Indian ink on, or mark with the indelible pencil, the exact point of each angle of the triangle before removing the sample, and to measure the distances between these points with the dividers after the sample has been removed, as shown in Fig. 15.

During measurement it is important that the surrounding skin should not be stretched by endeavouring to expose the dots to better view. If the forceps have been correctly adjusted earlier on, it will be found that they continue to hold the wool back from the bared triangle perfectly satisfactorily.

We suggest that the lengths of each of the three sides of the triangle should be noted on the envelope which also shows the number of the sheep and the date of taking the sample -together with other particulars necessary.

The area of the triangle may conveniently be determined by the usual formula as follows—

If the sides of the triangle are denoted by AB, BC, and CA; and if S=half the sum of these sides, the area is

$$\sqrt{S(S-AB)\,(S-BC)\,(S-CA)}$$

It is suggested that for convenience in measuring the sides of the triangle the metric system is the more satisfactory.

Modification of Technique - In fleeces where the density is great and where the fibres are entangled it is sometimes difficult to separate the wool fibres by means of a quill. To overcome this difficulty a triprong divider has been devised and used with success. This consists of the adoption of the principle of the three-armed uterine dilator—a human gynæcological instrument. Reference to Fig. 16 will make verbal description unnecessary. The closed instrument—with the three blades fitting together into a form which is in no way different from the essential of the quill or knitting needle— is used to pass into the fleece and along the line of the skin in exactly the same way as has been described previously. When in position the handles are closed and the three blades open out separating the wool fibres into two parallel lines. The longest blade carrying the dividing point—which is best made like an arrow-head—remains lying on the skin and the two shorter blades move upwards and outwards from it. Into the triangular space between the blades, a quill, or the fingers, can be readily inserted to complete the division of the fibres into two parallel walls. The remainder of the process does not differ from what has been already described.

SUMMARY

(1) A brief review is given of instruments and methods hitherto employed for determining fleece density.

(2) By modification of the earlier principles two other instruments have been devised and are described. The details of their construction and the technique of sampling with them, are illustrated.

(3) These instruments have been named the Wyedena and Wyedesa Fleece Calipers.

(4) A method of sampling employing a triangular area on the skin is described and its uses indicated.

(5) Some suggestions are offered for the evaluation of fleece density by the use of various formulæ.

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The block of the Mentzel Wool Density Measurer is used by the court of Urban and Schwarzenberg, Publishers, Berlin.

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